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VOLUME 18, NUMBER 4
DECEMBER, 1957

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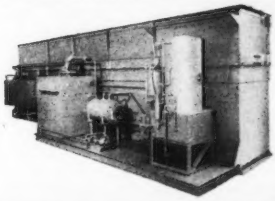

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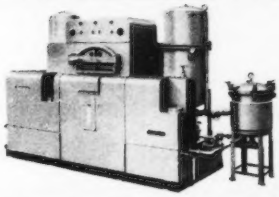

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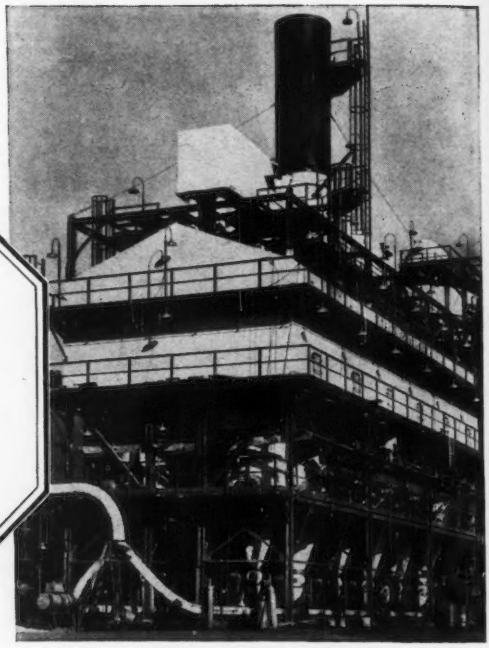

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✦ President's Page

THE Ad Hoc Committee on Certification has reported to the Board of Directors that it believes that the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION should undertake a program of certification in the broad field of industrial hygiene. The Board after studying the committee's report and thorough discussion has agreed as to the advisability of such action to strengthen the profession. As has been indicated previously, the officers and Board of Directors believe, that before embarking on such a program, the matter should be presented to the entire membership for final decision. Before asking each of you to express an opinion we shall attempt to present all available information to you before the forthcoming Atlantic City annual meeting. You will find material in your Newsletter, on this page and in special releases from time to time. In addition, at the suggestion of the Ad Hoc Committee on Certification, I have appointed a committee of seven past presidents under the chairmanship of DR. HENRY F. SMYTH to explore the method of approach and to prepare for the membership a proposal for setting up the mechanics for certification. It is expected that this committee will make its recommendations available to the membership before the next annual meeting. With this and other information, our members should be well equipped to make an intelligent decision on this vital matter.

ONE point I would like to stress is that there will be no connection between membership in AIHA and certification. Certification will not be a requirement for membership, but will be a device for attempting to establish and expand the stature of our profession and to provide recognition to any industrial hygienist, whether a member of AIHA or not, who meets the requirements set up by the certifying body.

IT IS OUR sincere hope that each of our members will well acquaint himself with all of the facets of this complex problem. As President of AIHA, I would appreciate receiving any comments or questions which members may have, for in order to be successful this program must have the support of a significant majority of our membership. Such support will rest on a full knowledge of the reasons for the undertaking as well as its impact on individual members.

Clarence R. Williams

Radiation Hygiene

ABOARD NUCLEAR SUBMARINES

Lt. Comdr. JOHN H. EBERSOLE, MC USN

OVER 2000 years ago Anacharsis succinctly stated a basic truth which applies to shipboard life: "There are three sorts of people: those who are alive, those who are dead, and those who are at sea." Today we can add a fourth classification — those who are at sea in submersibles; for the architecture, physical characteristics and function of a submarine place the submariner in an environment unlike any other. It is this unique and formidable environment, rather than the radiation problem per se, that is encountered in establishing a shipboard radiation hygiene program. The submarine environment influences all radiation control measures and is important enough to justify the principle that submarine radiation hygiene is more a function of the environment than of the degree or kind of radiation present. By comparison, the environment here has greater significance than in the industrial field.

Yet, while we emphasize the special environmental problem of the nuclear submarine and its variance from that of the industrial establishment, we must also mention basic similarities. The submariner, for example, may be considered as an industrial worker who has reached the ultimate in contact with his work environment. From this viewpoint, he is a 24 hour per day employee who must not only work, but must also eat, sleep, and find off-duty recreation but a few feet from his job at all times. As such, then he simply represents a special case in the field of occupational medicine and industrial hygiene. This basic relationship was recently described very aptly by Dr. Harry Alvis of the Navy's Medical Corps in the *New England Journal of Medicine:* "Comparison with the simultaneous evolution of occupational medicine in civilian practice clearly demonstrates that submarine medicine is a highly developed area of the broad pattern of occupational medicine." Some of these specific environmental factors that both differ and relate to shore-based industrial problems will be described in this article.

Presented at the Eighteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, April 26, 1957, St. Louis.

The Submarine Environment

VISUALIZE the submarine as a completely sealed streamlined pipe moving submerged several hundred feet below the surface of the sea. This sealed finite volume with its enclosed air has no contact with the earth's atmosphere. Here rests one of our environmental problems — *when submerged we cannot use the earth's atmosphere for dilution of airborne radioactivity.* The submarine may surface to ventilate, of course, but this requires time and may not be tactically possible or feasible.

Inside the ship's sealed volume a large central recirculation blower moves air through the ship via piping that opens into each compartment, supplying air to that compartment. Exhaust intakes in each compartment lead back to the suction side of the blower providing recirculation of ship's air when submerged. The rate of recirculation is brisk and potentially provides for rapid spread of airborne activity unless prompt measures are taken for isolation of contaminated areas from the ventilation system.

The submarine compartment arrangement is a horizontal one convenient for the control of contamination, but, even with the marked increase in space in our nuclear submarines, there is not room for set-

ting up personnel decontamination stations resembling anything in a shore based situation. The classical multi-staged decontamination station with directed flow horizontally through a series of rooms is as unrealistic as placing bowling alleys on submarines, and compromises are obviously necessary. One of the many difficulties here lies in the fact that showers are located some distance from the points of potential contamination and would require passage of contaminated personnel through living spaces.

Inside our sealed pipe is an amazing concentration of facilities. A submarine is a warship, not just an engineering plant, and, as such, requires huge masses of complex equipment as well as food stowage, cooking, eating, potable water, and sleeping spaces. This tremendous concentration of facilities produces a situation, for example, where food preparation and dining areas are less than 70 feet from the reactor system. No further description is necessary in order to emphasize the importance of contamination control under these conditions of proximity.

A further environmental factor of importance can be readily understood by again quoting Dr. Alvis: "Few industrial situations require the employee to remain at the factory overnight and all week long for as much as several weeks on end." Exposure rates versus stay times, for this reason, cannot simply be based on the 40-hour week. Continuous exposure situations in a casualty at sea require situational modifications of maximum permissible exposures and concentrations where these are based on the standard of a 40-hour week.

These are some of the major factors that must be considered in formulating the shipboard program. The submarine environment is not always antagonistic, however, and may often be used to advantage. In some ways the environment itself tends to simplify radiation control in comparison to shore based industry. The submarine, for example, is divided horizontally into a series of compartments by sturdy, watertight bulkheads. Access to each compartment is limited to one watertight door in each bulkhead. Simply by shutting and securing this door and shutting ventilation valves one can quickly isolate that compartment. This is the basis for casualty control procedures.

Among the advantageous environmental factors we must also include the high state of training of our submarine crews and their selection for intelligence and stability. These qualities are vital for the necessary cooperation required for good radiation hygiene. In a previous presentation we stated that the absorbtion coefficient of the human cerebrum is as important as that of our shielding materials. Pre-selection of personnel from this standpoint should be a goal of industry as important to a health physicist as his scaler circuits.

The relatively small number of people and the ease of communication aboard an operating submarine are additional helpful factors.

Radiation Hygiene Requirements

THE SHIPBOARD radiation control program on a nuclear submarine must possess a broad capability. This capability has to exist independent of a shore based installation for periods up to several months, and, must embrace fields of both engineering and biological interest. We mention the capability for obtaining engineering data because equipment used in the radiation hygiene program, such as counterscalers, also can double for procuring operational engineering data. In the narrow confines of a submarine one does not duplicate facilities where it is avoidable. For this reason such activity as the processing of coolant samples is arranged to obtain both engineering and biological information.

An important characteristic of the radiation control program is that it must function during in-port periods as well as at sea. Indeed, it is during reactor shut-down periods for maintenance, inspection, and upkeep that the health physics load reaches its peak. In this we do not differ from our shore based brethren. In such a maintenance situation in a port without support facilities, the ship's program must embrace all of the problems of issue of protective clothing, waste disposal, contaminated storage, and decontamination — not a small item of its over-all capability.

To summarize the requirements of the ship's program:

1. Provide a personnel dosimetry pro-

gram for beta, gamma, and neutron dosimetry.

2. Provide means for processing and quantitating primary coolant and associated liquids.

3. Provide means for radiochemical analysis, including analysis for fission products in liquid samples, including urine.

4. Collect and process air samples for measurement of airborne activity, including radioactive gases such as Argon 41.

5. Maintain a routine program for checking shield integrity and quantitating dose-rates.

6. Provide necessary calibration sources for film, dosimeters, and dose-rate meters (beta, gamma, and neutron).

7. Determine protective clothing requirements.

8. Establish and man control points in required situations.

9. Provide training programs for the crew.

10. Carry out personnel decontamination and supervise materiel decontamination.

In order to meet these requirements a small laboratory is provided the ship's Medical Department. The medical personnel consists of one doctor and two hospital corpsmen on both *Nautilus* and *Seawolf*. Under their cognizance is the laboratory which contains counting equipment, a film developing tank, and the usual adjuncts to a health physics program (see Figs. 1 and 2). The dimensions of the small laboratory may be of some solace to the shore based health physicist whose dreams of lebensraum are being frustrated. The total area of the laboratory is approximately 55 square feet, with only 14 square feet of floor space. Fortunately, one member of the Medical Department is off duty in his bunk under normal rotation when the remaining two are in the laboratory.

In considering the equipment and techniques available for health physics work on a submarine, we are confronted again with the influence of the submerged environment. We have considered this environmental influence on radiation control itself; this influence is equally as important in placing limitations on techniques and equipment. As an example, consider the effect of evaporating 24 hour urine samples in the enclosed volume of a submarine or of using methane mixtures in gas flow counters with the potential explosive hazard that may result in a confined space.

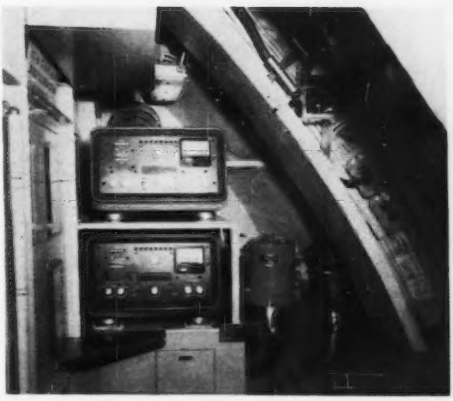

Fig. 1.
Ship's radiac laboratory showing sample counting area.

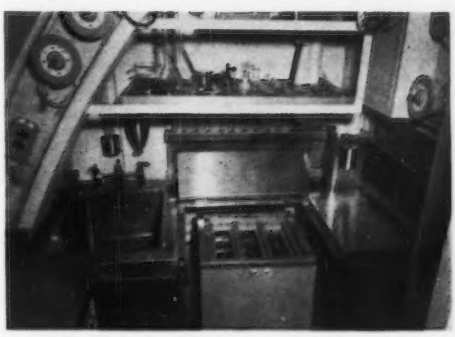

Fig. 2.
Ship's radiac laboratory showing film processing and chemistry area.

Radioactive Sample Counting Limitations

SAMPLE counting is done with end window Geiger tube techniques, both liquid and dry counting. One advantage of this method is the low backgrounds — as low as 11-15 counts per minute when submerged below 100 feet due to the shielding effect of sea water. Well-type scintillators were originally attempted, but high backgrounds, fluctuating with reactor power and normal ship vibration, were met. Simplicity, sta-

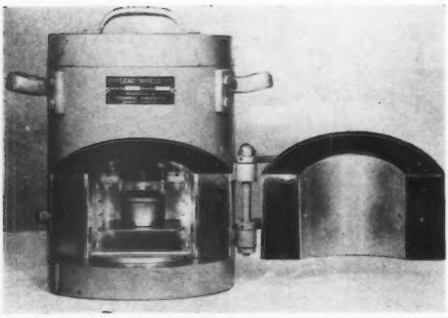

Fig. 3.
Geiger-Mueller liquid counter showing sample cup in place.

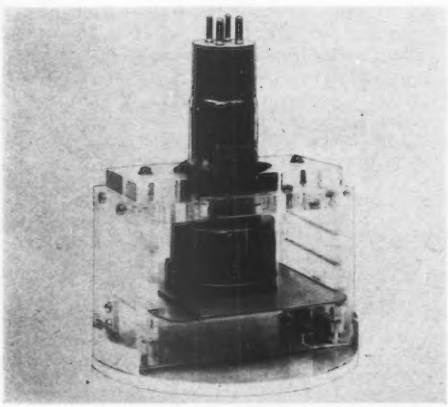

Fig. 4.
The jig, GM tube, and sample cup for liquid counting. The sample cup here is inverted over a metal spacer to check tube-cup distance. Note positioning peg near back of cup.

bility, and ruggedness favored the end window. Future techniques, particularly on surface ships, may favor the well type crystal counter; however, because the counting of liquid samples in a sealed vial is a distinct advantage on the rolling platform that a surface ship can be. Gas flow counters are prohibited because of the hazard inherent in gas mixtures inside a submarine. Here again, limitations posed by a submersible do not apply to surface ships.

Dry samples, air samples, and swipes are counted in the usual manner. Liquid samples are quantitated in a manner that will be described in detail. The liquid counted routinely is reactor coolant water which during reactor operation will approximate 1×10^{-3} microcuries per cc total activity. In this technique a 50 cc volume of liquid is carefully measured into a metal cup which is placed on a shelf below a standard end window tube. Fixed positioning pins in the shelf insure accurate positioning in the horizontal plane. Vertically the distance between the cup and tube is critical. Before placing the cup this tube-shelf distance is checked with standard spacers to insure accurate spacing (see Figs. 3 and 4). Standard radiation sources are provided for a further check to insure that line-up conditions are within a narrow range. The count rate obtained under these controlled conditions may then be referred to a calibration curve of microcuries per cc versus counts per minute. The curve is based on phosphorous 32 solutions of known activity, the maximum energy of P^{32} betas closely approximating that of the isotopes in coolant water.

This method is rapid and reliable for total activity checks and avoids necessity for evaporation. A definite advantage is the ease of teaching it to untrained personnel. The lower limit of sensitivity is 1.5×10^{-5} microcuries per cc. Below this level standard concentration techniques are used.

A complication in this method arises when the ship is surfaced in rough seas. To avoid spillage in this situation the sample cup is covered with Saran wrap held firmly in place by a metal rim which fits over the cup. Here a 10% positive correction must be made to the final concentration obtained. The possibility of spillage in rough seas is one factor that must be considered in any liquid technique. This will be even a greater problem in surface ships, since a submerged submarine is an ideally stable platform, despite any surface condition. Under rough sea conditions, therefore, a sealed vial of coolant in a crystal well has the advantage previously mentioned.

A similar system is used for atmospheric Argon 41 determinations (see Figs. 5A and 5B). Here a sample of air is collected in a cylindrical metal container. In squeezing the rubber bulb, air is pulled through a high efficiency filter in a metal holder and passes into the sample cylinder displacing

air through an open valve in the cylinder. Check valves insure air flow in one direction only. The upper surface of the sample cylinder is a sealed window of 30 mg per sq cm density. After flushing the system the cylinder valves are closed to trap the sample and the cylinder is positioned beneath the end window tube as with a liquid sample. After a suitable counting time the count rate is referred to a calibration curve to determine A^{41} concentration in air. Particulate air activity is removed by the filter and does not enter the sampling cylinder. The high density of the cylinder window limits all gas activitity "seen" to Argon 41 for practical purposes. The lower limit of sensitivity is 1.4×10^{-6} microcuries per cc at a twice background count rate. The source of A^{41} is dissolved air in reactor coolant water.

Both liquid and Argon 41 techniques were developed at the USN Material Laboratory, Brooklyn Naval Shipyard.

Radiochemistry Limitations

THE CHIEF compromise necessitated by the submarine environment in radiochemistry is the avoidance of volatile solvents and reagents. The finite volume of the submerged submarine with its common ventilation system cannot be contaminated with irritant or toxic fumes. Strong mineral acids, volatile hydrocarbons, ammonia, glacial acetic acid, and many other common reagents must be avoided and substitutes used, particularly in evaporation procedures.

Reagent substitution at times can be a problem, best described as going from the frying pan into the proverbial fire. An example is the substitution of non-volatile sodium hydroxide for ammonium hydroxide in alkaline precipitation techniques. A problem develops when reaction occurs between the sodium hydroxide solution and the atmospheric carbon dioxide, always present in low levels in a submerged submarine. Resultant weakening of the reagent occurs. This reaction can be avoided by the use of a stock saturated solution of Na OH. Storage and handling of such a caustic solution in the narrow confines of a submarine is dangerous and requires extreme caution. Any chemical technique must therefore, be examined in detail before acceptance.

Evaporation of urine samples on board presents a similar problem, although more esthetic than toxic, but can be expected to evoke a marked negative reaction from the crew. Acidified 24 hour samples can be collected at sea and later processed in port, except in extreme emergencies, as a solution to this problem.

Evaporation of any liquid sample is limited to the use of infra red lamps or hot plates as open flames are not tolerated in a submarine. This is not a serious limitation, but consideration in evaporation

Fig. 5A.
Argon 41 sampling device.

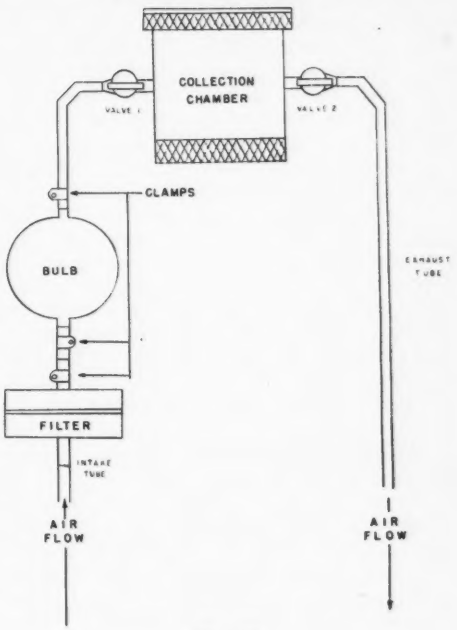

Fig. 5B.
Schematic of Argon 41 sampling device.

Fig. 6.
Film processing tank.

must also be given to the three dimensional capability of a submarine. Sudden and large down or up angles can abruptly end large volume evaporations. For this reason containers must be rigidly held in place over heating elements which in turn must be secured to prevent spillage.

Photodosimetry

THE NEED for an on board photodosimetry program with complete processing facilities presents minor problems in the areas of: (1) calibration, (2) storage, (3) temperature control during processing.

Calibration presents a problem at sea for the calibration source must be used inside the thick steel cylinder that is a submarine, introducing backscatter errors. Normally, open air calibrations are done on shore, but extended periods at sea may require film calibration inside the ship. A correction factor can be determined in port by comparison between open air and on board calibration and later applied at sea. Care must be taken to ensure that conditions are the same. The point is important if the correction factor is obtained in the torpedo room, a favorite area for calibration procedures, because the presence or absence of torpedoes can significantly alter geometrical considerations at a later date.

Film storage is in the ship's chill box comparable to refrigerators used on shore. No radiation levels are detectable in this area and no problems have arisen in storage. Contamination control in this area is obviously vital both for film and food supplies.

Adequate temperature control during processing is achieved in a small tank with a self contained coolant compressor and heating elements for temperature regulation of a water bath into which containers are placed for processing solutions (see Figs. 6 and 7). The system is a recirculatory one avoiding the use of large quantities of water which may be at a premium aboard a submarine at sea. No inherent agitation of the tank is required because of the small volume involved. Normal ship vibration would accomplish this at sea, although it is not required as temperature control has been adequate in port. The laboratory itself becomes a dark doom during film processing periods.

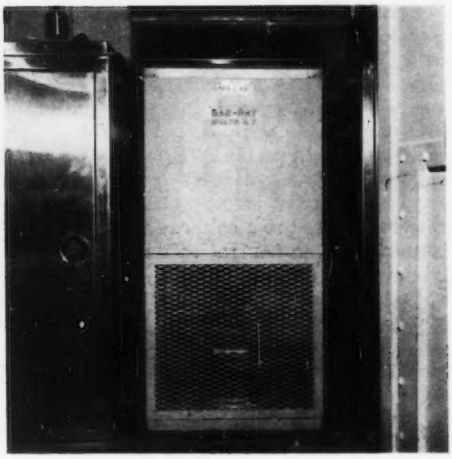

Fig. 7.
Film processing tank.

Source Limitations

THE BUILD-UP of radon and its daughters from radium sources presents both a biological and a nuisance problem inside a submerged submarine. Having prohibited the use of radium dials and markers aboard for this reason, we do not use radium for film, dosimeter, or instrument calibration. Instead, Cobalt 60 sources of various strengths are carried in the usual lead storage pigs without difficulty. Small strontium and uranium sources are also carried as beta sources. A radium D-beryllium source is used as a neutron source, radium D being used to avoid the radon generation problem.

Instrumentation

IN GENERAL, no specific environmental limiting factor arises here except that portable instruments, such as dose rate meters, must be rugged for shipboard longevity. Most commercial instruments are sadly lacking in this respect and standard Navy equipment is used almost entirely except for special evaluations. Contrary to what a non-submariner may believe, humidity problems do not normally exist. The air conditioning capacity of nuclear submarines in normal operation provides humidity control that would make a shore based health physicist envious. Vibration, being minimal, presents no problem, except as noted previously with one scintillator rig, and this appeared to be intrinsic to the particular device used.

End window mica Geiger tubes used in sample counting procedures must face one important environmental factor — that of abrupt changes in altitude while snorkeling. In snorkeling a valve located on top of the snorkel tube will close automatically in rough seas to prevent sea water from entering the tube. With this valve closed and diesel engines continuing to run, a *vacuum* is created inside the submarine which can simulate a rapid ascent to 4000 feet altitude before the diesels are secured. Although this is not a normal method of propulsion for nuclear submarines, it may be used on occasions. For this reason mica end window tubes which can withstand altitude changes are used to prevent tube rupture from expansion of the contained fill gas. These are simply tubes with low fill gas pressures such as the Tracerlab "L" series. Pressure changes in the opposite direction are no problem since atmospheric pressure inside a submerged submarine rarely exceeds 32 inches of mercury and is, for practical purposes, normal atmospheric pressure.

In the instrument field we are interested in future developments which will tend to minimize space requirements in a submarine. Two such considerations are miniaturization of present equipment and use of alternating current as the power supply for portable dose-rate meters. In the confines of a submarine one is never far from a 120 volt, 60 cycle electrical outlet. The necessity for finding space to store a multitude of spare batteries of different characteristics is a space problem of no small magnitude. Development programs are being carried out in this field.

Personnel Exposure

IN DESCRIBING the effects of submarine conditions on radiation control and attempting to emphasize the peculiar problems encountered, one is apt to make a pessimistic impression regarding personnel radiation exposure. Such is not the case, for the design and engineering of the propulsion plant is adequately adjusted to submarine existence. The best index of this is the exposure record during the first two years' operation of the *Nautilus*. In calendar year 1955 the following figures were obtained:

Average exposure	173 mrem per man per year
Maximum exposure	1500 mrem per year
Percent of crew with no exposure per year	Over 50%

In 1956 a similar pattern has been reported by Dr. Dobbins, present medical officer of the *Nautilus*. Average exposure per man per year was slightly over 200 mrem, with a maximum exposure of 2200 mrem per year. The increase is not considered significant and represents the effect of increased operations during 1956.

It can be concluded that radiation control as a function both of design and operation can be excellent even in the complex environment of a submersible.

Summary

The importance of submarine environment on radiation control has been emphasized. The limiting effect on certain routine health physics techniques has been detailed, and the shipboard equipment for these techniques described.

The submarine environment places additional demands on radiation control due to proximity and continuous exposure. The watertight construction characteristics facilitate radiation control. Space limitation, ship motion and encapsulation limit routine health physics techniques and compromises had to be devised. Personnel exposure on the *U.S.S. Nautilus* during the initial two years of operation is of an extremely low order of magnitude.

Annular Kinetic Impactor

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THIS is a preliminary report of one aspect of an over-all study designed to test the applicability of an annular impactor described by Tait,[1] to the sampling of airborne radioactive particulate contaminants at the Savannah River Plant. Such an instrument is of interest at this installation in connection with the possibility of establishing working requirements in radioactively contaminated areas. In its ability to separate particles of different mass, it eliminates the necessity of waiting for decay of some types of particles to determine presence of others.

A previous report[2] has indicated that a definite possibility exists for the detection of radioactively contaminated particulates over a radon background by use of the impactor principle. Accordingly, the primary objective of this aspect of the study was to (1) design an impactor for use with the Staplex air sampler; and (2) to determine the relative collection efficiency of this unit for atmospheres contaminated with plutonium, fission products, and radon daughters. Other investigations[3,4] now in progress at Savannah River are concerned with applying the impactor principle to constant air monitoring devices.

Discussion

AN IMPACTOR was designed for use with the Staplex, Model TF1A, portable air sampler. The completed assembly (Figs. 1 and 2) was capable of sampling air at the rate of 50 cu ft/min, which corresponds to an orifice velocity of 454 linear ft/sec. Theoretical calculations indicate that this device should impinge on the sampling tray all particles down to 0.4 micron in diameter which have densities greater than 15 gm/cm^3.

Collection efficiencies for particles within the range of the impactor were determined by connecting two identical impactors in series (Fig. 3). The efficiency of the collecting material used to trap the particles is then obtained from the ratio of the activities deposited on each sample tray. The mathematical development, outlined in Fig. 3, gives the final equation:

$$\text{Efficiency} = 1 - \frac{B}{A}$$

where A = activity on first tray
B = activity on second tray.

The contamination per cubic foot of air does not appear in the final equation, thus eliminating the necessity of calibrating the

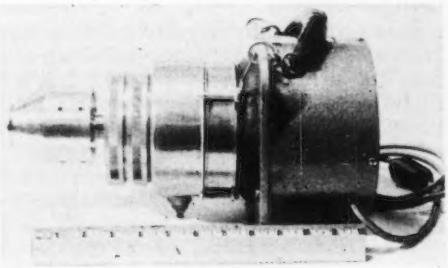

Fig. 1.
Annular Impactor.

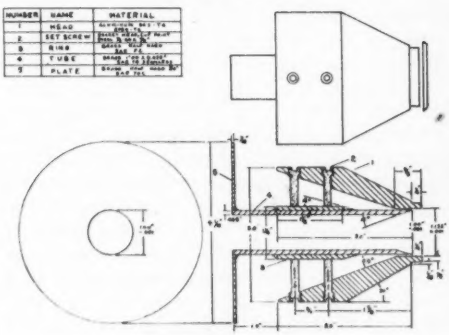

Fig. 2.
Diagram of Annular Impactor.

instrument in an atmosphere of known contamination. The activities, "A" and "B," may be expressed in any convenient terms. Counter factors and geometrical considerations are eliminated if the same counter is used when the ratio is taken.

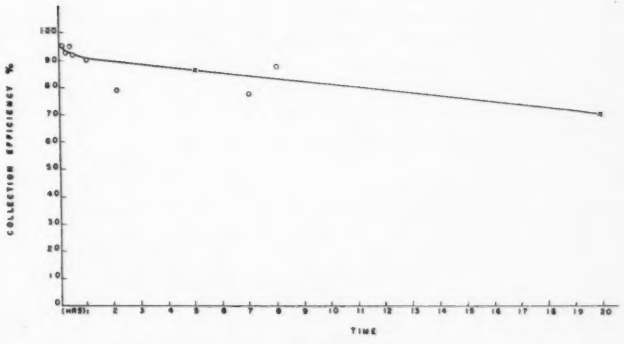

Fig. 4.
Sampling time vs. collection efficiency. Impactor sampling using Dow Corning 200 fluid.

Experimental Results

ONLY one of many possible collecting materials, Dow Corning 200 fluid, was evaluated during this test. Other collecting media will be evaluated.

The following collection efficiencies were obtained in various types of contaminated atmospheres:

Material Sampled	Number of Samples Taken	Average Collection Efficiency, %	Standard Deviation
Plutonium	15	93.4	6.5
Fission Products	18	91.8	10
Radon Daughters	89	1.7	1.2

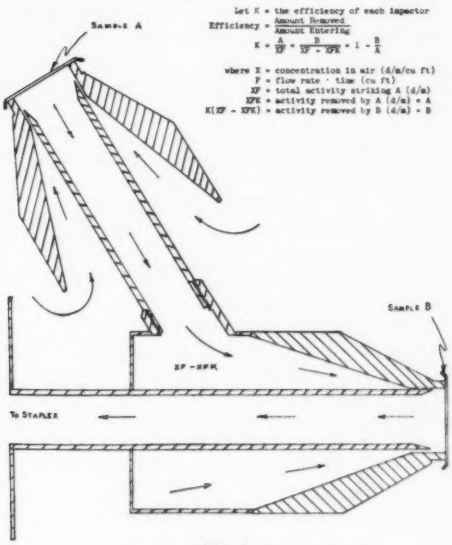

Fig. 3.
Calibration attachment.

The collection efficiency was found to be constant up to a sampling time of 20 minutes. Longer sampling periods cause a decrease in collection efficiency due to the dust particles covering the surface of the grease. For plutonium, the average collection efficiency dropped from 95% for a 10-minute sample to 75% after continuous sampling for 24-hours (Fig. 4).

Self-absorption of alpha activity in the grease was found to be 55.4% with a standard deviation of 19. This self-absorption increased after the sample set for several days due to the particle physically settling into the grease. The beta self-absorption, measured on five samples, indicated that the beta activity lost in the grease is less than 5.0% with a standard deviation of 3.3.

A particle size study of the active particles removed by the impactor indicated that 89% of the active particles were above one micron in diameter and 11% below. The majority of the particles (52%) were between one and five microns which, according to Davies,[5] is the size range most likely to be retained by the alveola.

Procedure

THE COLLECTING planchet is very lightly greased by spreading a thin coating of Dow Corning 200 fluid over the surface with a gloved finger. The greased planchet is placed over the small end of the impactor and held in place until the air sampler is turned on.

Flow rate and sampling time are recorded

on the sampling envelope. A sampling time of 10 to 20 minutes is recommended. After the sample has been taken, the dust-laden planchet is placed back into the envelope for transportation to the counter. The sample is counted in the usual manner and the results recorded.

Interpretation of Data

1. The concentration of airborne plutonium in $\mu c/cc$.

$$\mu c/cc = \frac{(c/m - 4\ c/m^*)\ (\text{Counter Conversion Factor})}{(2.22 \times 10^6\ d/m/\mu c)\ (2.83 \times 10^4\ cc/cu\ ft)\ (0.95)\ (0.50)\ (\text{Volume, cu ft})}$$

$$= \frac{(c/m - 4\ c/m)\ (\text{Counter Conversion Factor})}{(2.98 \times 10^{10})\ (\text{Volume, cu ft})}$$

* The average alpha count due to radon daughters is about 4 c/m and must be subtracted from the initial net alpha count.

2. Concentration of fission products in air.

$$\mu c/cc = \frac{(c/m - 20\ c/m^{**})\ (\text{Counter Conversion Factor})}{(2.22 \times 10^6\ d/m/\mu c)\ (2.83 \times 10^4\ cc/cu\ ft)\ (0.95)\ (0.70)\ (\text{Volume, cu ft})}$$

$$= \frac{(c/m - 20\ c/m)\ (\text{Counter Conversion Factor})}{(4.17 \times 10^{10})\ (\text{Volume, cu ft})}$$

** The average beta activity due to the radon decay products is approximately 20 c/m. Again, this must be subtracted from the initial net beta count.

The average alpha count of 4 c/m, and the average beta count of 20 c/m, may vary widely under certain atmospheric conditions. Such conditions as (1) extremely dirty atmospheres, (2) very high humidity, and (3) extreme inversion conditions, on occasions, may cause the alpha and beta counts to be unusually high. If high counts do occur, investigation of the atmospheric conditions should be initiated. However, masks should be worn in critical areas until such results are evaluated.

Summary

AN ANNULAR impactor was designed for use with a Staplex air sampler. The collection efficiencies for radioactive particles in air were determined by collecting the samples on a tray coated with Dow Corning 200 fluid. It was found possible to detect the maximum permissible concentrations of alpha, beta, and gamma-emitting contaminants by sampling for a 10-minute period.

Collection efficiency for these contaminants was approximately 95%. This compares favorably with the 98% collection efficiency of Whatman No. 41 filter paper. The collection efficiency for the radon decay products, however, was 5% for the impactor and 50% for the Whatman No. 41 sampler.

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Scientific Exhibits

THE AMERICAN INDUSTRIAL HYGIENE ASSOCIATION Scientific Exhibits Committee wishes to solicit AIHA members for scientific exhibits to be shown at the Industrial Health Conference in Atlantic City in April, 1958. Anyone interested should write for further information or for space application to: A. C. PABST, Socony Mobil Oil Company, Inc., 150 East 42nd Street, Room 1401, New York 17, New York.

Pre-operational Environmental Survey for a Power Reactor

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The operation of a reactor plant presents the possibility that radioactive material may be released in sufficient amounts to increase the levels of radioactivity in the surrounding environment. If an increase over pre-existing levels is to be observed, it is necessary to know what these background levels are before the plant goes into operation. The pre-operational environmental survey is carried out to determine these levels. The scope of such a survey, the sensitivity limits and the requirements they impose on methods and instruments are discussed.

IN SPITE of every practicable precaution, the operation of a power reactor offers the possibility of releasing sufficient amounts of radiation and radioactive material to increase the levels in the environment surrounding the plant. As a consequence of this ever-present possibility the operators must be able to recognize any significant increases in environmental levels that are related to plant operation.

If the environment contained no radioactive materials, the detection and measurement of material released by the plant would be a relatively simple matter. Radiations and radioactive materials are, of course, always present, and many of them existed long before man began tinkering with the atom. In order to recognize a significant increase, it is necessary to know what the levels are before the plant goes into operation.

Presented at the Eighteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, April 25, 1957, St. Louis.

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The pre-operational environmental survey is carried out to characterize the levels of radiation and radioactivity that prevail in the neighborhood of the plant before it goes into operation. There is a three-fold purpose to such a survey: First, it will make possible the prompt recognition of any increase in environmental levels, related to plant operation, so that the cause may be found and corrected long before levels of any significance to health are reached. Second, the survey will reduce the number of false alarms arising from high levels unrelated to plant operation to the minimum consistent with the first objective. And finally, the survey will protect the plant from claims of injury and damage unrelated to plant operation.

For these purposes, environmental characterization will consist of the following determinations: (1) Average levels of radiation and average concentrations of radioactive materials. (2) The ranges through which these levels fluctuate, the nature of any recurring cycles and patterns, and any correlations with meteorological conditions. (3) The types of radiations and radioactive materials present in the environment.

These data will establish a baseline, and the nature of this baseline so that it will be possible to know if, and to what extent, reactor operation changes the environmental conditions in the region.

The following factors define the scope of a pre-operational survey: (1) duration of the survey, (2) limits of sensitivity, (3) media sampled, (4) radiations and materials to be measured, (5) distance out from the plant, (6) number of sampling locations, and (7) frequency of sampling.

A detailed discussion of each of these factors is not possible here, but it is proper to note that today there is a great diversity

of opinion on many of these factors. Standards of good practice have yet to be evolved.

There is fairly general agreement that the minimum period which ought to be covered by a pre-operational survey is 12 months in order to encompass the annual cycle exhibited by many of the quantities of interest. Preferably the survey will last 18 months and cover two summers to allow for equipment failure and acquired wisdom and give some indication of yearly variation.

The limits of sensitivity required of the instruments and methods are dictated in part by the maximum permissible exposure for the public, and also in part by the desire to obtain numbers rather than zeros whereever possible.

For some years now the maximum permissible levels for occupational exposure have been based on the figure 0.3 rem per week, or 15 rem per year. By convention, the maximum permissible levels for non-occupational, i.e., public exposure have been taken as 1/10 of this, or 1.5 rem per year. Recently several national and international groups have recommended reductions of some of these maximum permissible exposures in the light of possible genetic consequences in a world of expanding atomic energy applications. Dr. Karl Morgan has recently reviewed these deliberations and has summarized the lower maximum permissible exposures that will probably result from them.*

Table I gives tentative values for the new maximum permissible exposure levels. The first row of figures is for whole body exposure to external radiation. Since these involve exposure of the gonads, the maximum permissible occupational value is 1/3 of the old value, i.e., 5 rem per year. Non-occupational exposure near controlled areas is taken as 1/10 the occupational value, i.e., 0.5 rem per year. Maximum exposure for the public at large is taken to be that which will double the natural background radiation, i.e., about 0.1 rem per year in addition to the background radiation.

The most toxic β emitter is strontium-90, and the most toxic α emitter associated with reactor operation is plutonium-239. Both of these are bone seekers and involve little exposure to the gonads. So consequently, the old MAC values apply for these materials in air and water. The concentrations in column I are for 40-hour-per-week exposure and are obtained from NBS Handbook 52. The concentrations for strontium and plutonium in columns II and III are obtained by multiplying the Handbook 52 concentrations for continuous exposure by 1/10 and 1/50 respectively.

The MAC's for most radioactive materials are set in consideration of one or another critical organ. In no case are the gonads the critical organ. However, in the case of the noble radioactive gases argon, krypton and xenon, MAC's are set by whole body exposure, so that concentrations listed in the table for three of these isotopes are reduced to 1/3 of the older values, following the same line of reasoning used to obtain the values for external exposure.

The figures given in Table I for large population groups may differ from those finally adopted by as much as a factor of two, but such an uncertainty is not important for the present considerations.

The tentative MAC's for public exposure given in Table I present some interesting problems. With conventional counting equipment an air sample of about 30,000 cubic feet must be drawn through a filter to permit accurate measurement at these concentrations. Such a sample can be drawn in a week's time by any of a number of available air pumps, but the layer of dust that builds up on the filter presents two difficulties. First, as the dust layer builds up, the pressure drop across the filter will increase, and the rate of flow through the filter will tend to decrease. To some extent this difficulty can be circumvented by self-compensating pumps. The second difficulty is that α particles, and to a lesser extent, β particles will be absorbed by the overlying dust layer on the filter and cannot be counted.

The maximum dust layer through which a reasonably constant air flow can be maintained, and through which α and β particles can be counted with fair accuracy is about 4 mg/cm^2. In order to draw 30,000 cu ft of air with a dust load typical of a residential city (1.4 mg/m^3) and not exceed a dust layer on the filter of 4 mgm/cm^2, a circular filter about 8" in diameter is required. A

* MORGAN, K. Z.: Maximum Permissible Dose of Radionuclides: Recent Changes in Values. *Nuclear Science and Engineering*, 1:477-500, 1956.

filter this size can be counted only with a large counter. Alternatively, one may extract the material on the filter chemically, or draw a smaller air sample and use special counters with very low background counting rates. A similar line of reasoning leads to a water sample of 300 liters as the minimum necessary to measure the public MAC for strontium-90 with conventional counting equipment.

Table II serves to illustrate several other aspects of a pre-operational environmental survey. The first column designates the medium from which the sample is drawn: air, surface water (meaning streams, rivers and lakes), ground water (meaning wells

TABLE I.
TENTATIVE NEW MAXIMUM PERMISSIBLE EXPOSURE LEVELS

Exposure	I Occupational, in Controlled Areas 5 rem/yr (0.1 rem/week) μc/ml	II Non-occupational, Near Controlled Areas 0.5 rem/yr (0.01 rem/week) μc/ml	III Large Population Groups 0.1 rem/yr (0.002 rem/week) μc/ml
External radiation* In Air			
Sr^{90} + Y^{90}	6×10^{-10}	2×10^{-11}	4×10^{-12}
Pu^{239}	6×10^{-12}	2×10^{-13}	4×10^{-14}
A^{41}*	5×10^{-7}	1.7×10^{-8}	3.4×10^{-9}
Kr^{85} (4.4 hr)*, **	2×10^{-6}	7×10^{-8}	1.4×10^{-8}
Kr^{85} (10 yr)*, **	3×10^{-6}	1×10^{-7}	2×10^{-8}
In Water	μc/ml	μc/ml	μc/ml
Sr^{90} + Y^{90}	2.4×10^{-6}	8×10^{-8}	1.6×10^{-8}
Pu^{239}	4.5×10^{-6}	1.5×10^{-7}	3×10^{-8}

*Critical organ is whole body, i.e., gonad exposure is limiting.
**Calculated by the method of NBS Handbook 52.

TABLE II.
SAMPLING LOCATIONS

Media	Type of Sample	Sampling Method	Number of Collecting Locations[1] On Site	½ to 5 Miles	Beyond 5 Miles	Beyond Plant[2] Influence	Total
Air	Fall-Out + Rain-Out	Collecting Trays	10	50	50	10	120
	Particulates	Filter, Integrating[3]	2	4	6[4]	2	14
	Particulates	Filter, Continuous					
	β-γ Radiation	Counter, or Ion Chamber, Continuous	2	2	2[4]	1	7
	γ Radiation	Counter, or Ion Chamber, Continuous					
	Meteorologic[6]	Continuous	1	1	1	0	3
Surface Water	Water	Proportional	1	2[7]	2[7]	1	6
	Water	Spot					
	Mud + Silt	Spot					
	Fish	Spot	2	6	6	2	16
	Plants	Spot					
	Bivalves	Spot					
	Algae + Plankton	Spot					
Ground Water	Water	Proportional	1	2[8]	2[8]	0	5
	Water	Spot	3	4[9]	6[9]	3	16
Sewage	Water + Solids	Spot	1	2	2	1	6
Land	Soil	Spot					
	Plants	Spot	3	8	8	4	23
	Animals[10]	Spot					

1. all quantities are to be taken as ± 50%
2. to provide a background reference after the plant is in operation
3. continuous collection, read-out of average at 1-7 day intervals
4. one or more of these stations might be mobile
5. continuous collection, read-out of average at 3-12 hour intervals (radiation monitors at 30-60 minutes)
6. meteorological variables: wind speed, wind direction, temperature and precipitation
7. at first point of use
8. at representative wells used for drinking water
9. at all other wells used for drinking water
10. including cows' milk, if any

and springs), sewage, and land. The second column describes the type of sample, and the third the method of collecting the sample. The next four columns give an estimate of the number of collecting locations on the site, off-site to a distance of five miles, beyond five miles and finally out beyond the possible influence of the plant.

Data from locations beyond the plant influence are included to provide background reference after the plant goes into operation. With such data, a general, transient increase in radiation or radioactivity resulting from natural causes or bomb testing will not be attributed to plant operation. As more and more reactor survey networks go into operation, and as state and federal public health agencies begin to carry out similar surveys, such reference data will be provided without the need for particular stations.

To avoid any possible misunderstanding it must be emphasized that the quantities in Table II cannot be regarded as either accurate or objective. They should be taken as personal estimates for a general case. The most one can hope is that they may be found to have an overall accuracy of ±50%.

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Diffusion and Deposition
in relation to reactor safety problems

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AT THE request of the Atomic Energy Commission, Brookhaven National Laboratory has recently completed an intensive study of the hazards associated with nuclear power plants. Instead of confining the investigation to an individual reactor in some particular location, an attempt was made to derive conclusions applicable to the majority of power reactors and sites now under consideration. The study was also unusual in that it was a genuine group effort and represents a wide variety of viewpoints and disciplines. Officially, nine individuals are listed as the study team, but more than a score contributed substantially to the investigation, and many others provided helpful advice and criticism. The full report will shortly be available from the Government Printing Office, under the title "Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Power Plants."

The purpose of this paper is to review the role of atmospheric diffusion and deposition processes in hazard evaluation, but a few comments concerning other parts of the work are both interesting and necessary as background information. Any reactor hazard analysis has three natural subdivisions, dealing, respectively, with release, distribution, and consequences of the discharge of fission products. Clearly, the study group concluded that a major release was possible, despite the elaborate control devices and containment vessels included in all power reactor designs. Had this not been true, there would have been no need for the work on diffusion and deposition. It must be emphasized, however, that a large scale release of fission products was considered an extremely remote possibility. No specific figure for this probability was included, since the various means of deriving such figures — (1) past experience, (2) composite probabilities of successive or simultaneous events, and (3) average values of considered opinions — all failed to produce useful information.

It is surprising that with the variety of power reactors, containment schemes, sites, and population distributions currently under consideration, anything typical could be chosen, but it is believed that the hypothetical model selected contains quite representative features. The reactor was considered to be a 500,000 thermal KW unit, fueled with U^{235} utilized in a fuel reprocessing cycle of 180 days. Such a reactor was calculated to contain total fission product activity in the amount of 4.1×10^8 curies. Some of the important constituents are as follows:

Iodine	5.0×10^7 curies
Noble gases	3.4×10^7 curies
Strontium^{89}	1.7×10^7 curies
Strontium^{90}	3.0×10^5 curies
Cerium^{144}	8.0×10^6 curies

Two types of accidents resulting in a release to the atmosphere were postulated. The first assumed a breach in the container, allowing volatile fission products and part of the strontium inventory to reach the atmosphere. The second was a major accident accompanied by enough heat to rupture the containment vessel, from which 50% of the entire fission product inventory escaped. It is not important in terms of this paper to specify precisely how these events were presumed to occur. Mechanisms for each could be visualized, and neither could be ruled out as impossible. It is significant, however, that both were considered improbable, with the major 50% release significantly less probable than the volatile fission product release.

Research carried out under the auspices of the United States Atomic Energy Commission.

LIST OF SYMBOLS

Symbol	Description	Units*
h	height of cloud	m
n	stability parameter	dimensionless
$\bar{\chi}$	mean dosage	curies sec/m³
Q or Q_o	pollutant emission	curies
C_y	horizontal diffusion parameter	$m^n/2$
C_z	vertical diffusion parameter	$m^n/2$
$\bar{u}$	mean wind speed	m/sec
x	distance downwind	m
y	distance crosswind	m
z	vertical distance	m
$\triangle$	rate of deposition	curies/m²
P	rate of rainout	curies/m²
V_g	velocity of deposition	cm/sec
λ	proportion of cloud removed per sec. by rain	1/sec

*Those not specified are included in the text or tables.

From the meteorological point of view, the task was to translate these releases into cloud dosage and particulate deposition downwind of the reactor site. Thus, the objective was definition of the distribution of the fission products. Evaluation of the consequences of contamination formed yet another part of the study, and is not considered in the present paper.

Site and Climatology

THE FIRST step was to establish a typical site complete with appropriate climatological statistics. This, like many other of the generalization problems, proved simpler than had been anticipated, and the very fact that the reactor was restricted to electric power generation helped considerably. Such a reactor is usually designed to serve a municipal area, and would logically be placed at a distance from the population center commensurate with economical land and transmission costs (30-35 miles). A substantial source of fresh water is a necessity, so that it was also possible to specify location near a lake or river. Of the two, the river is believed more probable. These facts permit construction of a rough map of the idealized site, shown in Fig. 1. The two-mile valley width with 200-foot ridges parallel to the river and north-south orientation is purely imaginative, but in no way unrealistic.

From a survey of U.S. climatological records and available micrometeorological studies, a synthetic microclimatology was developed and is presented in Tables I and II. The first entry in Table I may be expected to surprise individuals unfamiliar with microclimatology, for the temperature inversion is still generally thought of as an uncommon phenomenon. Actually, the assignment of 50% of all hours to the inversion category is quite in keeping with microclimatological studies such as those at Savannah River[2] and Brookhaven.[6] Oak Ridge data[3] would even suggest the possibility of a value greater than 50% for a valley location.

The selection of typical lapse rates and mean air temperatures needs little explanation or justification. There are wide variations in both over the United States, but the numbers used are realistic. The same may be said of the percentage of hours of rainfall and the association with lapse and inversion cases. The normal and moderate rainfall rates were selected from unpublished studies at Brookhaven.

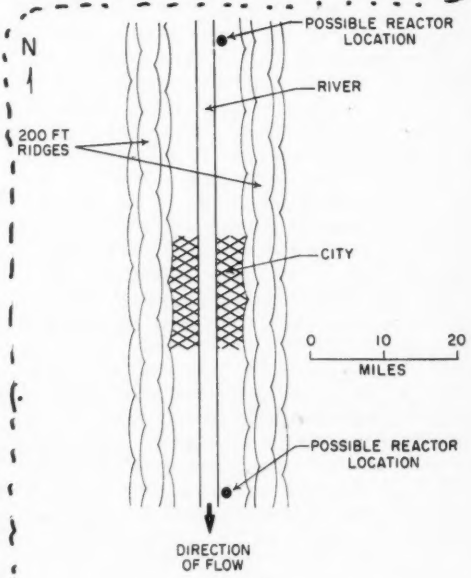

Fig. 1.
Imaginary reactor location in the United States.

TABLE I.
METEOROLOGICAL PARAMETERS FOR AN IDEALIZED SITE

Frequency of Occurrence (percent)	Thermal Stability: Lapse 50 (normally day, but many nights also)	Thermal Stability: Inversion 50 (generally night and early morning)
Lapse rate (°C/100 m)	−1.0	+1.0
Mean air temperature (°F)	60	40
Hours with precipitation (percent)	13	2
Mean wind speed at ground-level (m/sec)	5.0	3.0
Mean wind speed at 400-800 meters (m/sec)	15.0	15.0
Total annual precipitation	40 in/yr	
Most probable rainfall rate	0.02 in/hr	
Rainfall rate exceeded by 10 percent of hours	0.15 in/hr	

TABLE II.
WIND DIRECTION FREQUENCIES FOR AN IDEALIZED SITE
(percent)

Direction	Ground-Level: Lapse	Ground-Level: Inversion	Aloft (400 - 800 m): Lapse and Inversion
North	7.5	22.5	10
Northwest	10.0	5.0	20
West	5.0	5.0	20
Southwest	7.5	5.0	20
South	10.0	2.5	10
Southeast	2.5	2.5	5
East	2.5	2.5	5
Northeast	5.0	5.0	10
Totals	50.0	50.0	100

The upper level wind distribution in the final column of Table II reflects a predominant westerly flow very common in middle latitudes. The division of the ground-level winds into lapse and inversion hours is in accordance with the well-known "channeling" effects of valleys, and is especially noticeable in the 22.5% frequency assigned to northerly (down valley) inversion winds. It is also common knowledge that a relation usually exists between wind direction and rainfall, but this is such a widely varying feature of climatology that it was decided to consider rainfall hours independent of wind direction.

The wind speeds of 3.0 and 5.0 m/sec selected for the ground-level inversion and lapse cases, respectively, were chosen to represent flow near, but not necessarily at the ground over relatively long distances. The upper level winds would not be expected to show any important diurnal variations, and were chosen as 15 m/sec for all cases.

Tables I and II provide all the usual meteorological parameters necessary for the computation of the probability of various weather conditions existing at the time of an accident. While a much larger number of specific conditions should be investigated to give a complete representation of the probable fate of the fission products, it is believed that the range of injury and damage reflected by various combinations of these includes about 95% of the possible cases.

One important feature of the meteorological analysis, as well as much of the other material in the report, is that there was a lack of conscious bias toward pessimistic values of the parameters. The meteorological approach, in all its details, was completed before any of the consequences of the assumptions were known. It should not be inferred from this that the selection of theoretical models and values of the parameters is considered good. On the contrary, many portions are very uncertain, as will become evident in the development of the various phases.

Initial Cloud Behavior

ONE OF the most important and most difficult portions of the meteorological study was specification of the cloud behavior immediately after release. This was true both because of the difficulty of specifying the exact nature of the release from the reactor, and because of scanty knowledge concerning the behavior of small clouds and jets. In terms of the latter, the difficulties stem largely from the lack of suitable field tests for comparison with existing theoretical models. Much recent attention has been devoted to nuclear bomb clouds, but these are too large and too hot for the current scale of interest. Data of the right scale, derived from chemical explosions or combustion, are usually by-products of other studies and do not include sufficient information for an acceptable analysis.

In this study, the equation of Sutton[8] was selected for the daytime ascent and the Hol-

land modification[4] was applied to nocturnal conditions. These predicted heights of 860 meters in lapse conditions and 400 meters during inversions for clouds of sufficient heat and pressure to rupture the containment shell.

It was recognized that release of volatile products probably would not be hot, and also that the major failure could occur slowly enough to prevent any effective ascent. The study therefore proceeded on the basis of essentially three types of release: (1) a hot cloud rising to 860 meters during the daytime, (2) a hot cloud reaching 400 meters at night, and (3) a cold cloud at ground-level regardless of the time of day.

The effects of the initial behavior are far-reaching in terms of both direct dosage from the radioactive cloud and deposition of particulates in dry weather. In succeeding sections, this is illustrated by an analysis of the major release only. The volatile case can usually be treated as a simple percentage of the cold 50% release, and is of no particular interest in the analysis of distribution as such.

TABLE III.
DIFFUSION PARAMETERS USED IN THE STUDY

Meteorological Conditions	Height (m)	n (dimensionless)	C_y ($m^n/^2$)	C_z ($m^n/^2$)	$\bar{u}$ (m/sec)
Typical Lapse	0	0.25	0.40	0.40	5.0
	860	0.25	0.40	0.40	15.0
Typical Inversion	0	0.55	0.40	0.05	3.0
	400	0.55	0.40	0.05	15.0

Diffusion

MANY attempts have been made to derive expressions for the diffusion of gases or aerosols in the atmosphere. It is questionable that any can be defended rigorously on theoretical grounds, but several could be used with acceptable accuracy if appropriate values of the diffusion parameters were introduced. The treatment of Sutton[9] seemed especially appropriate, since it possesses the flexibility necessary for the study, and is familiar to all engaged in micrometeorology. In particular, the basic equation for a continuous point source was used as the diffusion model:

$$\bar{\chi}(x,y,o) = \frac{2Q}{\bar{u}\pi\, C_y C_z\, x^{2-n}} \exp. - \left[\frac{y^2}{C_y^2\, x^{2-n}} + \frac{h^2}{C_z^2\, x^{2-n}}\right] * \qquad (1)$$

As had been stated, it is difficult to specify exact nature of the release, but if the total quantity of fission products in curies is substituted for the rate of release (Q), the result, $\bar{\chi}$, is given in the convenient dosage unit of curie-sec/m^3. This is of direct use to individuals evaluating the consequences of an accident.

The added considerations necessary in a radiation study, such as attenuation, decay and build-up factors, were all included in the establishment of specific dosage values that were used to delineate injury and damage categories.

Selection of appropriate values for the diffusion parameters was hampered by the same lack of appropriate field data that had been a problem in determining the ascent of the cloud. Either measurements had been made from a source which was too large, such as nuclear bomb tests, or low-level sources had not been studied to sufficient distances. Clearly, a cloud diffusing in the stratosphere is of little use, and the extrapolation of data such as Brookhaven's, which is measured only to within 10 kilometers, is questionable. Another limitation brought forth in the analysis of diffusion data was that most studies have been made under lapse conditions. The nocturnal inversion case, which occurs approximately 50% of the time, has seldom been studied quantitatively. Fortunately, it was possible to obtain some information concerning the dispersion over long distances for the inversion case from Thomas[10] of the Tennessee Valley Authority. These were helicopter measurements of the concentrations of SO_2 up to 50 miles from a steam plant. They supplement local inversion studies made at Brookhaven[7] with Kytoons. Both are continuous sources rather than isolated clouds, but they have helped greatly in the final selection of the parameters given in Table III.

Since the diffusion parameters are critical to all aspects of the study, it is important to examine Table III carefully. The

*All symbols are defined in the "List of Symbols."

most noticeable feature is that no allowance has been made for variation of the parameters with height, except in the case of the mean wind speed (u). This is based on the fact that the diffusion occurs over greater distances than any previously studied, and it is doubtful that the variations with height shown in short-distance tests are pertinent. In terms of wind speed, it is well known that an important increase usually exists in approximately the first 2000 feet above ground, and this is reflected in the values shown.

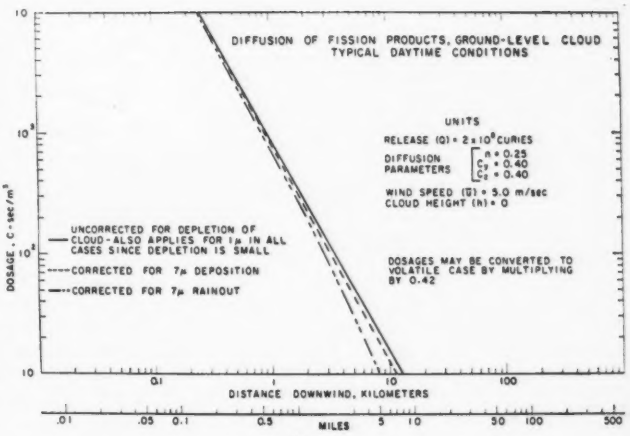
DIFFUSION OF FISSION PRODUCTS, GROUND-LEVEL CLOUD
TYPICAL DAYTIME CONDITIONS
UNITS
RELEASE (Q) = 2 x 10⁶ CURIES
DIFFUSION PARAMETERS n = 0.25, Cy = 0.40, Cz = 0.40
WIND SPEED (U) = 5.0 m/sec
CLOUD HEIGHT (h) = 0
UNCORRECTED FOR DEPLETION OF CLOUD - ALSO APPLIES FOR 1μ IN ALL CASES SINCE DEPLETION IS SMALL
CORRECTED FOR 7μ DEPOSITION
CORRECTED FOR 7μ RAINOUT
DOSAGES MAY BE CONVERTED TO VOLATILE CASE BY MULTIPLYING BY 0.42
DOSAGE, C - sec/m³
DISTANCE DOWNWIND, KILOMETERS
MILES

Fig. 2.
The dosages directly downwind of the reactor are shown. Since deposition and rainout actually remove a portion of the particles, the corrected curves are included.

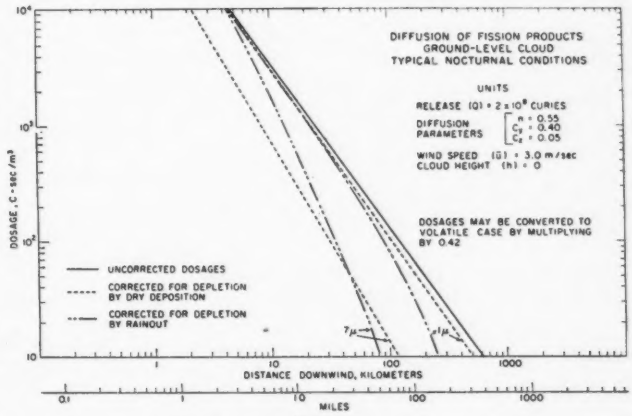
DIFFUSION OF FISSION PRODUCTS
GROUND-LEVEL CLOUD
TYPICAL NOCTURNAL CONDITIONS
UNITS
RELEASE (Q) = 2 x 10⁶ CURIES
DIFFUSION PARAMETERS n = 0.55, Cy = 0.40, Cz = 0.05
WIND SPEED (U) = 3.0 m/sec
CLOUD HEIGHT (h) = 0
DOSAGES MAY BE CONVERTED TO VOLATILE CASE BY MULTIPLYING BY 0.42
UNCORRECTED DOSAGES
CORRECTED FOR DEPLETION BY DRY DEPOSITION
CORRECTED FOR DEPLETION BY RAINOUT
7μ
1μ
DOSAGE, C - sec/m³
DISTANCE DOWNWIND, KILOMETERS
MILES

Fig. 3.
The dosages directly downwind of the reactor are shown. Since deposition and rainout actually remove a portion of the particles, the corrected curves are included.

No serious quarrel is anticipated with the use of 0.25 for n in the daytime conditions, since most investigations have shown values close to this. The same be said of the 0.40 value for both C_y and C_z during lapse conditions. The use of 0.55 during the inversion case is considerably less firm, and the main justification is that it fits the TVA data rather well. The choice of 0.05 for the nocturnal C_z again is in rough accordance with the meager information available. It is almost certainly no larger, and it may be as small as 0.02. The use of 0.40 for C_y during the inversion reflects the belief that strong horizontal wind shear is maintained even during very stable conditions.

The importance of these parameters is illustrated by the dosage configurations shown in Figs. 2 and 3, in which the solid lines represent the dosages directly downwind of the reactor for a cold release in which the cloud centerline begins and remains at ground-level. This approximation is obtained by settling $y = h = o$ in equation (1). The very great difference between night and day is immediately evident, for important dosages extend to hundreds of kilometers at night as compared to approximately 10 during the daytime. This is associated with the very small vertical diffusion ($C_y = 0.05$) and the very large stability parameter ($n = 0.55$) applied to the inversion condition.

Figs. 2 and 3 are indicative only of conditions along cloud center-line. Obviously, the width must be defined if the nature of the

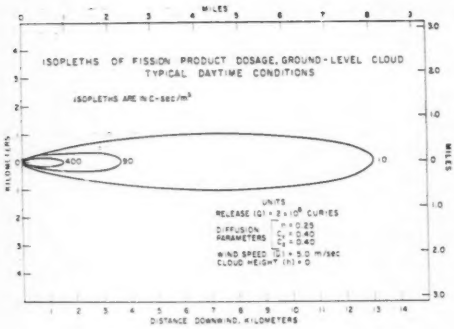

Fig. 4.
Isolines of constant dosage (C-sec/m³) are shown in a horizontal plot. No correction for deposition or rainout is included.

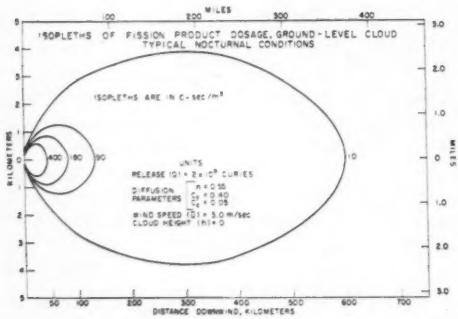

Fig. 5.
Similar to Fig. 4, except for different distance scale.

hazard is to be evaluated. This was accomplished by computing dosage isolines. Those shown in Figs. 4 and 5 represent significant dosage limits as specified by the health physicists and biologists of the Brookhaven team (Table IV). The important point to note is the tremendous difference in area resulting from changes in diffusion parameters. The 10 c-sec/m³ isopleth, for example encloses an ellipse roughly 600 x 8 km during inversions as compared to one 13 x 2 km during the day.

The other interesting feature of the diffusion analysis appears when the hot cloud sources are compared to those at ground-level. Figs. 6 and 7 are plots derived from precisely the same assumptions as those used to obtain Figs. 2 and 3, except for the cloud heights and the wind speeds. Here also, the difference between lapse and inversion is evident in terms of distance, but in neither case does the dosage reach the minimum damage level of 10 c-sec/m³.

Deposition and Rainout

DIFFUSION studies provide a basis for evaluating the direct effects of the cloud as it passes over the countryside, but they give no indication of the particulate residue that may be transferred to ground surfaces, vegetation, and buildings. The term "transferred" is used initially instead of deposition or rainout to suggest the lack of quantitative knowledge concerning the processes that are actually involved. It is known that small particles may be influenced by many forces other than simple gravitational settling. Ranz and Johnstone[5] have shown that impaction, electrostatic and thermal forces may be equally important for 1μ particles This is also shown by the recent experiments in which deposition of uranium fume was measured. Similarly, a simple treatment probably does not describe scavenging by rain where the hygroscopic nature of the particles may be as important as their size and shape. Forms of precipitation other

TABLE IV.
SUGGESTED LIMITS
RADIATION DOSAGE AND DEPOSITION

Category		Full F.P. Release C-sec/m³
A	Lethal exposure	>400
B	Illness likely	400 - 90
C	Injury unlikely, but some expense may be incurred	90 - 10
D	No injury or expense	<10
Range		C/m²
I	Urgent evacuation (within 12 hr) necessary	>0.2
II	Evacuation necessary	$>10^{-2}$
III	Severe restrictions on land use, possible temporary evacuation, restrictions on outdoor work	10^{-2} - 10^{-3}
IV	Probable destruction of standing crops, restrictions on agriculture for first year	10^{-3} - 10^{-4}
V	No expense likely	$<10^{-4}$

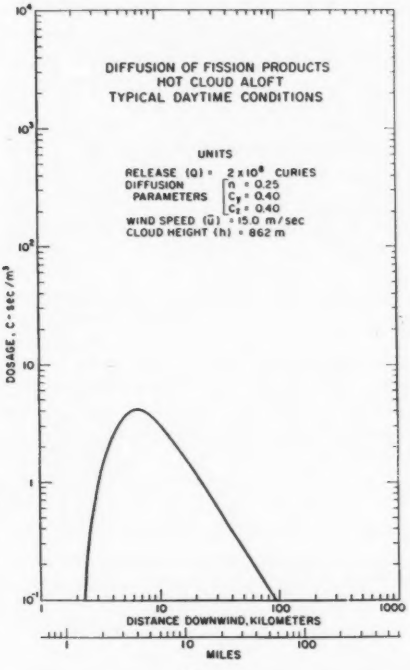
DIFFUSION OF FISSION PRODUCTS
HOT CLOUD ALOFT
TYPICAL DAYTIME CONDITIONS
UNITS
RELEASE (Q) = 2 x 10⁸ CURIES
DIFFUSION PARAMETERS n = 0.25, C_y = 0.40, C_z = 0.40
WIND SPEED (ū) = 15.0 m/sec
CLOUD HEIGHT (h) = 862 m
DOSAGE, C - sec/m³
DISTANCE DOWNWIND, KILOMETERS
MILES

Fig. 6.
Similar to Fig. 2, except that dosage does not occur continuously at the ground. Curves adjusted for rainout and deposition have not been included since the maximum dosages are so low.

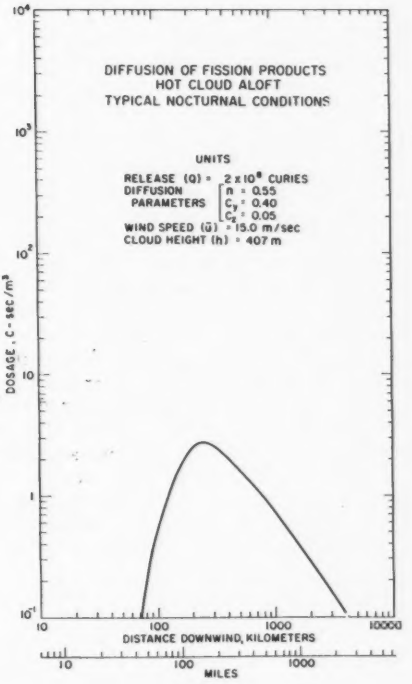
DIFFUSION OF FISSION PRODUCTS
HOT CLOUD ALOFT
TYPICAL NOCTURNAL CONDITIONS
UNITS
RELEASE (Q) = 2 x 10⁸ CURIES
DIFFUSION PARAMETERS n = 0.55, C_y = 0.40, C_z = 0.05
WIND SPEED (ū) = 15.0 m/sec
CLOUD HEIGHT (h) = 407 m
DOSAGE, C - sec/m³
DISTANCE DOWNWIND, KILOMETERS
MILES

Fig. 7.
Identical to Fig. 3, except for meteorological conditions.

than rain present even more complicated problems.

Unfortunately, scientific knowledge of the right type for this study is even more inadequate than that applying to diffusion. The most probable reasons are that complete field experiments in deposition and rain-out of small particles are extremely difficult to conduct, and there has been little need until the present. All the limitations confronting meteorologists mentioned in the section on diffusion can be repeated here, together with a host of others. Theoretical work and laboratory studies have dealt with idealized spherical particles under conditions unlike those in the atmosphere. Field experience with bomb tests has covered a satisfactory range of particles, but the most interesting sizes from the point of view of reactor hazards are largely confined to the stratosphere.

Paint pigments, such as zinc or cadmium sulphide, have been used largely as tracers rather than for quantitative analyses.

In any case, it is apparent that little justification exists for the use of analyses more sophisticated than simple settling approximations until more research has been completed. Accordingly, the straight-forward approach to dry deposition and rainout prepared by Chamberlain[1] was used without alteration in the study. In dry weather it is assumed that the small particles are brought close to the ground by turbulent diffusion, and that deposition occurs from the lower portion only. This is stated in equation (2), which is simply the basic diffusion equation multiplied by a velocity of deposition (V_g) and corrected for the removal of particles by the first exponential term.

A serious question arose in regard to the probable particle size range of fission prod-

$$\Delta = \frac{2Q_o\ V_g}{\overline{u}\pi C_y\ C_z x^{2-n}} \exp\left[-\frac{4V_g x^{n/2}}{\overline{nu}\pi^{1/2} C_z} \right] \exp - \left[\frac{y^2}{C_y^2 x^{2-n}} + \frac{(h^2)}{C_z^2 x^{2-n}} \right] \quad (2)$$

ucts released from the reactor. It seems most probable that a release would occur as a result of or in combination with combustion, with the particles having the general characteristics of a fume. The size distribution fitting this description would certainly be very small. However, one cannot rule out an accident of different nature giving a much larger particle size distribution. Table V shows the two distributions selected for consideration in the study. Figs. 8 and 9 represent the deposition for these two particle size groupings during day and night conditions from ground-level clouds. The figures are essentially duplicates of Figs. 2 and 3, except that deposition rather than direct cloud dosage is plotted. They show much the same relationship with meteorological conditions, in that the important deposition values extend much further downwind during inversions. The small particulate group deposits more slowly, and results in contamination smaller by a factor of about 100 at any distance of importance during the daytime. The depletion of the

TABLE V.
PARTICLE SIZE DISTRIBUTIONS*

	Size μ	Percent by number	Percent by weight
Group having 1.0μ mass median diameter	0.5	95	40
	1.5	5	60
Group having 7.0μ mass median diameter	1.5	15	1
	3.5	60	16
	7.0	23	45
	15.0	2	38

*Typical fume and dust distributions are shown.

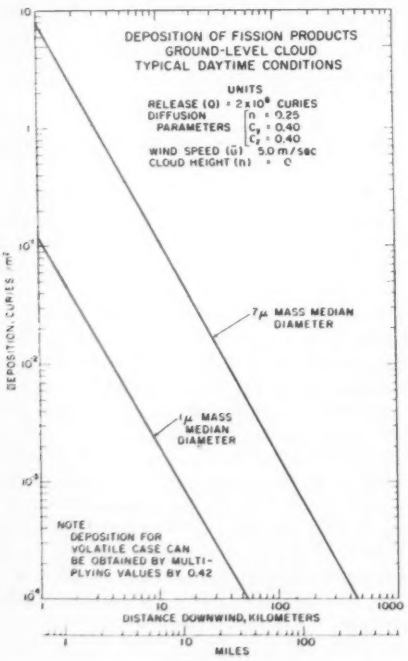
DEPOSITION OF FISSION PRODUCTS
GROUND-LEVEL CLOUD
TYPICAL DAYTIME CONDITIONS
UNITS
RELEASE (Q) = 2x10⁸ CURIES
DIFFUSION PARAMETERS n = 0.25, Cy = 0.40, Cz = 0.40
WIND SPEED (ū) = 5.0 m/sec
CLOUD HEIGHT (h) = 0
7μ MASS MEDIAN DIAMETER
1μ MASS MEDIAN DIAMETER
NOTE
DEPOSITION FOR VOLATILE CASE CAN BE OBTAINED BY MULTIPLYING VALUES BY 0.42
DEPOSITION, CURIES / m²
DISTANCE DOWNWIND, KILOMETERS
MILES

Fig. 8.
Dry weather deposition is shown for the two particle size distributions shown in Table III.

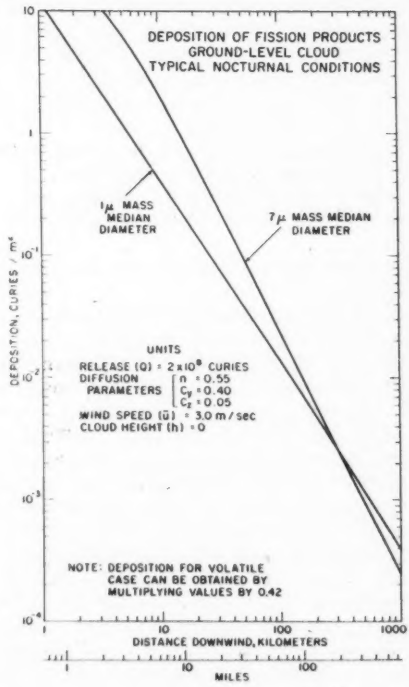
DEPOSITION OF FISSION PRODUCTS
GROUND-LEVEL CLOUD
TYPICAL NOCTURNAL CONDITIONS
1μ MASS MEDIAN DIAMETER
7μ MASS MEDIAN DIAMETER
UNITS
RELEASE (Q) = 2x10⁸ CURIES
DIFFUSION PARAMETERS n = 0.55, Cy = 0.40, Cz = 0.05
WIND SPEED (ū) = 3.0 m/sec
CLOUD HEIGHT (h) = 0
NOTE: DEPOSITION FOR VOLATILE CASE CAN BE OBTAINED BY MULTIPLYING VALUES BY 0.42
DEPOSITION, CURIES / m²
DISTANCE DOWNWIND, KILOMETERS
MILES

Fig. 9.
Counterpart of Fig. 7. Note that 1.0u particles become most important beyond 300 km.

cloud of larger particles becomes noticeable at great distances during inversions, however, and beyond 300 km the 1μ cloud gives greater deposition than the 7μ simply because there is much more material remaining in the air.

Plots of the deposition curves associated with the hot cloud cases are not included, for they add nothing to the discussion. Deposition from the 7μ group exceeds that from the 1μ cloud at all distances and levels of interest, and in neither lapse nor inversion cases are very large areas affected by heavy deposition.

Rainout has been treated in a similar manner using the same two particle distributions and settling rates, and considering all precipitation as rain. Chamberlain's[1] formula describing the process is as follows:

$$P = \frac{Q_o \exp(-\lambda/\bar{u})}{\bar{u}\pi^{1/2} C_y x^{2-n/2}} \exp - \frac{y^2}{C_y^2 x^{2-n}} \qquad (3)$$

This equation differs sharply from (2) in that all terms associated with height (h) or vertical diffuson (C_z) disappear. This simply means that the relatively rapid fall of the raindrops brings any collected particle to the ground almost instantly, no matter what its initial location within the cloud. The implication of this is very important. No advantage is gained from the rise of a hot cloud, so that all releases are effectively treated as cold except for the important variation of wind speed with height.

A second important feature becomes apparent only when the data for various cases are plotted. This is the very marked attenuation of the total content of the cloud by the rainout process, given mathematically by the term exp $(-\frac{\lambda}{\bar{u}})$. A table of λ values as a function of particle size and rainfall rates is shown in Table VI.

TABLE VI.
RAINOUT OF SMALL PARTICLES

Particle Diameter (μ)	Proportion of Cloud Removed per Second (λ)	
	Rainfall 0.02 in/hr	Rainfall 0.15 in/hr
0.5	1.0×10^{-5}	2.0×10^{-5}
1.5	1.5×10^{-5}	3.0×10^{-5}
3.5	6.0×10^{-5}	3.0×10^{-4}
7.0	1.5×10^{-4}	7.0×10^{-4}
15.0	2.0×10^{-4}	1.0×10^{-3}

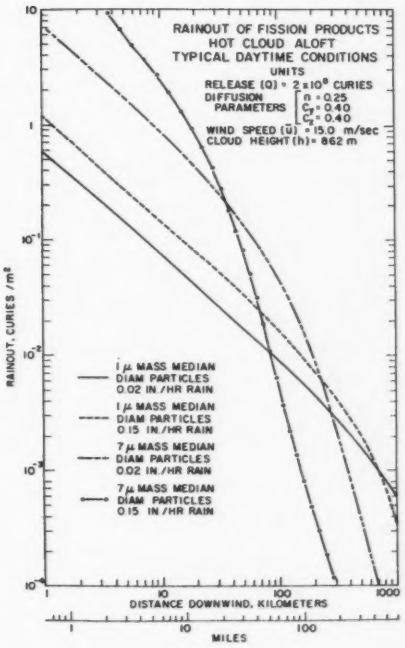
RAINOUT OF FISSION PRODUCTS
HOT CLOUD ALOFT
TYPICAL DAYTIME CONDITIONS
UNITS
RELEASE (Q) = 2 x 10⁸ CURIES
DIFFUSION PARAMETERS n = 0.25 Cy = 0.40 Cz = 0.40
WIND SPEED (ū) = 15.0 m/sec
CLOUD HEIGHT (h) = 862 m
1 μ MASS MEDIAN DIAM PARTICLES 0.02 IN./HR RAIN
1 μ MASS MEDIAN DIAM PARTICLES 0.15 IN./HR RAIN
7 μ MASS MEDIAN DIAM PARTICLES 0.02 IN./HR RAIN
7 μ MASS MEDIAN DIAM PARTICLES 0.15 IN./HR RAIN
RAINOUT, CURIES /m²
DISTANCE DOWNWIND, KILOMETERS
MILES

Fig. 10.
Curves for the two particle size distributions and two rainfall rates are shown.

It is necessary to compare carefully the plots for the various meteorological conditions, particle sizes and rainfall rates to see the possible ground contamination patterns (Figs. 10-13). However, it is almost immediately apparent that the initial height of the cloud offers no advantage. In fact, comparison of the hot and cold cases during nocturnal conditions reveals that the elevated cloud results in greater deposition except very close to the source. This may be attributed primarily to the greater wind speed aloft, which carries the cloud further before the same percentage of depletion is achieved.

The rainout process is such a complex relation of rainfall rates, diffusion parameters, wind speeds and particle sizes that it is hard to fit any very simple rules. In most cases, however, small particulates may have much more serious consequences in terms of the size of the contaminated area. Restrictions on agriculture (10^{-3} to 10^{-4} c/m^2), for example, would extend further down-

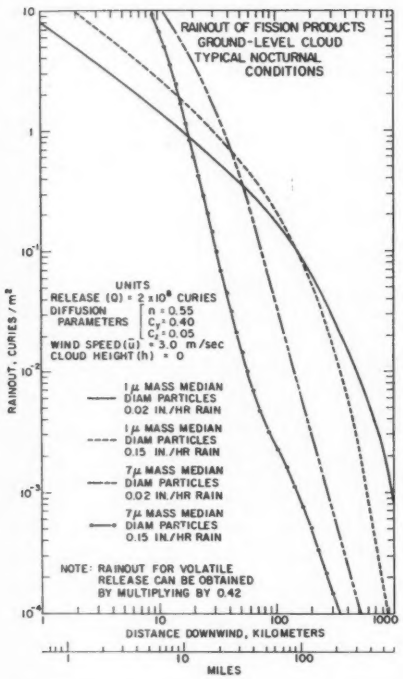
RAINOUT OF FISSION PRODUCTS
GROUND-LEVEL CLOUD
TYPICAL NOCTURNAL
CONDITIONS
UNITS
RELEASE (Q) = 2 x 10⁸ CURIES
DIFFUSION PARAMETERS n = 0.55 Cy = 0.40 Cz = 0.05
WIND SPEED (ū) = 3.0 m/sec
CLOUD HEIGHT (h) = 0
1 μ MASS MEDIAN DIAM PARTICLES 0.02 IN./HR RAIN
1 μ MASS MEDIAN DIAM PARTICLES 0.15 IN./HR RAIN
7 μ MASS MEDIAN DIAM PARTICLES 0.02 IN./HR RAIN
7 μ MASS MEDIAN DIAM PARTICLES 0.15 IN./HR RAIN
NOTE: RAINOUT FOR VOLATILE RELEASE CAN BE OBTAINED BY MULTIPLYING BY 0.42
RAINOUT, CURIES / m²
DISTANCE DOWNWIND, KILOMETERS
MILES

Fig. 11.
Similar to Fig. 10, but much more rapid depletion removes most of the material dose to the source.

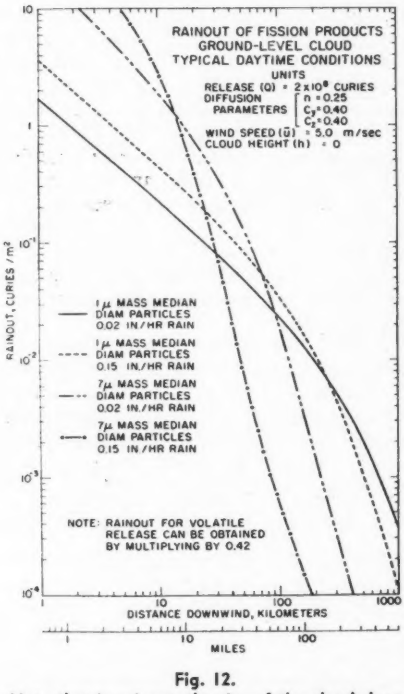
RAINOUT OF FISSION PRODUCTS
GROUND-LEVEL CLOUD
TYPICAL DAYTIME CONDITIONS
UNITS
RELEASE (Q) = 2 x 10⁸ CURIES
DIFFUSION PARAMETERS n = 0.25 Cy = 0.40 Cz = 0.40
WIND SPEED (ū) = 5.0 m/sec
CLOUD HEIGHT (h) = 0
1 μ MASS MEDIAN DIAM PARTICLES 0.02 IN./HR RAIN
1 μ MASS MEDIAN DIAM PARTICLES 0.15 IN./HR RAIN
7 μ MASS MEDIAN DIAM PARTICLES 0.02 IN./HR RAIN
7 μ MASS MEDIAN DIAM PARTICLES 0.15 IN./HR RAIN
NOTE: RAINOUT FOR VOLATILE RELEASE CAN BE OBTAINED BY MULTIPLYING BY 0.42
RAINOUT, CURIES / m²
DISTANCE DOWNWIND, KILOMETERS
MILES

Fig. 12.
Note that in rainout, the rise of the cloud does not prevent important deposition on the ground.

wind with small particles in each of the four cases shown.

All other factors remaining constant, an increase in the rainfall rate tends to augment rainout close to the source and decrease it at greater distances. This effect is much more prominent with light winds than with strong ones.

Comparison of these curves with dry deposition cases shows that rainout has more serious consequences. This is often true of the hot clouds which would produce only minor deposition in dry weather, but could affect tremendously large areas with rainfall.

Probabilities

IN THE foregoing, the major factors affecting the dispersion and deposition of fission products have been discussed as individual subjects. The fact that the major release itself is most improbable has been stressed, but it is also interesting to review the probabilities of the various meteorological occurrences in the event of such a failure. This is a relatively simple matter of combining the synthetic climatology and the site map given earlier.

For the conditions postulated, no matter what the location or the nature of the accident, it is always probable that there will be no rain and that the cloud will not move toward the city, with a slight preference for an inversion condition over a lapse. Only in the case of the northern location is there a relatively large change of movement of the cold, ground-level cloud toward the city during an inversion, and this reflects the channeling of the wind flow at night. Rain occurring at the time of an accident would usually be associated with lapse conditions and the movement would tend to be away from the city. The combination of rain and inversions is relatively uncommon.

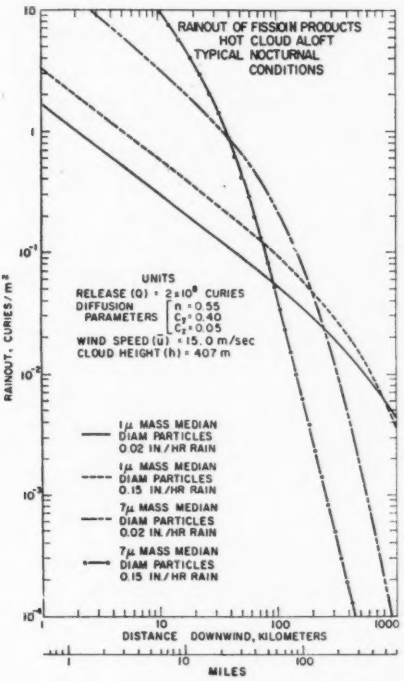
RAINOUT OF FISSION PRODUCTS
HOT CLOUD ALOFT
TYPICAL NOCTURNAL
CONDITIONS
UNITS
RELEASE (Q) = 2×10⁸ CURIES
DIFFUSION PARAMETERS n = 0.55
Cy = 0.40
Cz = 0.05
WIND SPEED (ū) = 15.0 m/sec
CLOUD HEIGHT (h) = 407 m
1μ MASS MEDIAN DIAM PARTICLES 0.02 IN./HR RAIN
1μ MASS MEDIAN DIAM PARTICLES 0.15 IN./HR RAIN
7μ MASS MEDIAN DIAM PARTICLES 0.02 IN./HR RAIN
7μ MASS MEDIAN DIAM PARTICLES 0.15 IN./HR RAIN
RAINOUT, CURIES/m²
DISTANCE DOWNWIND, KILOMETERS
MILES

Fig. 13.
Similar to Fig. 4.

Summary and Conclusions

THE foregoing is a resumé of portions of the recent Brookhaven study of the hazards associated with power reactors. Attention has been centered on the distribution of fission products that might accompany a major reactor failure, and therefore is largely concerned with meteorological processes.

Despite our inability to achieve high accuracy in many of these estimates, it is perfectly clear that the possible range of direct cloud dosages and ground contamination by fission products is very large indeed. Changes in meteorological conditions alone could mean the difference between a relatively minor event and a major catastrophe. It is not easy to generalize about the problem, because of the many factors involved, but a few obvious features do stand out.

Most apparent is the major influence of atmospheric stability on the distance to which important concentrations and contamination may extend. It also has a most significant effect on the magnitude of the dosage and deposition values, but the increase in distance with increasing stability is virtually always present.

A second generalization may be made concerning normal rainfall associated with clouds composed of small particles. The typical rainfall, which is relatively light, greatly increases the deposition close to the source, and usually extends the isolines of significant contamination to much larger distances than would be the case in dry weather.

Not to be neglected is the ascent of a hot cloud. In dry weather, an initial rise of only a few hundred meters may reduce contamination downwind by several orders of magnitude. This rule cannot be applied during precipitation, and may in fact be reversed because of the more rapid movement of the debris.

Finally, careful site selection in relation to meteorology and topography can reduce the probability of injury and damage to an important degree. This paper has used the distances and areas of contamination as yardsticks, and the evaluation of the importance of meteorology is based upon them. However, consideration of population distributions, land values and land use, as has been done in the full study, in no way diminishes the importance of meteorology in site planning.

Acknowledgments

THE AUTHORS have already stressed the fact that much of the material represents the work of other team members involved in this study, but it is felt that Kenneth W. Downes, the Project Director, deserves particular credit for his help in keeping all of the efforts carefully oriented toward the central objectives. In terms of the meteorological study itself, there were many important contributors. Foremost are F. E. Bartlett, R. M. Brown, and S. Rottenberg of the Brookhaven Meteorology Group, who have devoted countless hours to the tedious process of completing and checking the calculations. In the planning and development of the study, P. H. Lowry, of Johns Hopkins, and L. Machta and D. Pack, of the U.S. Weather Bureau, have been most help-

ful. Many individuals have assisted in the procurement of data and background information, but particular credit is due F. W. Thomas and F. E. Gartrell, of the Tennessee Valley Authority, who provided very valuable new data on inversion concentrations as soon as their field tests were completed. Dr. A. C. Chamberlain, Atomic Energy Research Establishment, made an outstanding contribution in summarizing recent British experience in this field, and in his pertinent suggestions. J. Z. Holland, of the U.S. Atomic Energy Commission, has reviewed each step of the development with a thorough critical appraisal invaluable to the authors.

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Training Courses in Air Pollution

THE Air Pollution Training Section, Robert A. Taft Sanitary Engineering Center, is offering six courses in air pollution during late 1957 and early 1958. The course material is designed for chemists, engineers, and other scientists in State and local health departments, control agencies, and industrial groups. The schedule of courses is as follows:

November 12-22, 1957	Atmospheric sampling
January 13-24, 1958	Atmospheric sampling analysis
February 17-21, 1958	Detection and control of radioactive pollutants in air
March 10-12, 1958	Air pollution effects on vegetation
April 7-11, 1958	Source sampling and analysis
April 14-18, 1958	Control of air pollution sources

Applications and further information may be obtained from PAUL F. WOOLRICH, Chief, Air Pollution Training Section, Robert A. Taft Sanitary Engineering Center, USPHS, 4676 Columbia Parkway, Cincinnati, Ohio.

Toluene Diisocyanate

Engineering and Medical Control of Exposures in Polyurethane Foam Manufacturing

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KENNETH E. JAMES and WARREN LUNDY
United States Rubber Company, Chicago
W. S. WALSH, M.D., Chicago

SEVERAL reports in both European and American literature[1,2,3,4,5] in recent years have brought out the possibility of respiratory irritation and possible inhalation sensitization in individuals working with the diisocyanates.

Our experience with toluene diisocyanate began in November, 1954. From the inception of production, the diisocyanate used has been a mixture of 65% toluene 2,4-diisocyanate, and 35% toluene 2,6-diisocyanate. In simple terms, the basic operation consists of a reaction between two carefully prepared solutions — one, a mixture of a catalyst, water and resin; and the other, a resin-isocyanate mixture to produce a polyurethane foam. This is then quickly poured into a mold. Our operations are primarily in the production of foam-lined instrument panels for automobiles.

The evolution of the process, through several stages of equipment changes has a significant bearing on our experience. The original installation consisted essentially of two canopy hoods — one enclosing the mixing operation, and the other, the pouring operation (Fig. 1). This equipment was used for nearly a year, without too much difficulty. For most of this time, the number of operators was small, possibly six or seven persons. There were also several changes in the ventilating equipment. The original fan had a capacity of only 800 cfm. This was replaced by a fan of 2,000 cfm in December. In March, 1955, when the first air tests were made with concentrations of TDI in excess of 0.1 ppm, the fan was again changed to provide 5,000 cfm, and 100 fpm at the face of the hoods. Other changes, such as the addition of side curtains, and a plexiglass shield at the mixing operation were also made.

The second stage in the evolution of the process is shown in Fig. 2. This occurred in July, 1955. The operation makes use of an enclosed ventilated mixing booth, a ventilated pouring station, and an enclosed belt conveyor. Fan capacity was 8,000 cfm providing exhaust ventilation at the mixing station, the pouring station, and the conveyor enclosure. Personnel at this operation involved about six people per shift.

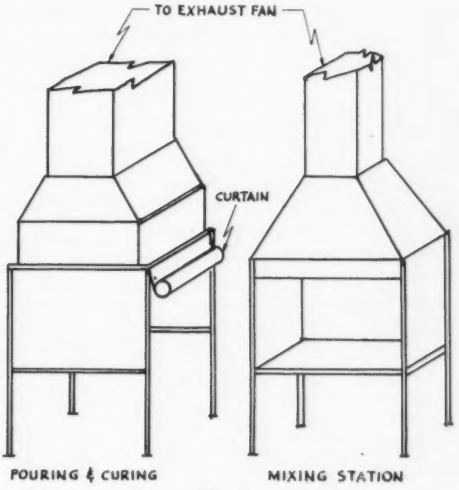

Fig. 1.
Original installation.

Presented before the Eighteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, April 25, 1957, St. Louis.

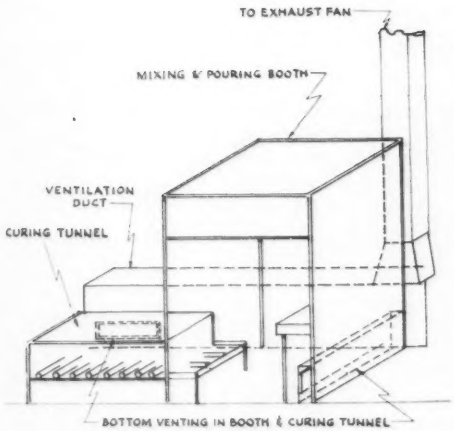

Fig. 2.
Temporary mixing, pouring and curing.

The third and present stage of the process development appeared in October, 1955, nearly a year after the original installation. Figs. 3, 4 and 5 illustrate the ventilation of this equipment. The two mixing stations, and other sources of fume production are ventilated by fans with a total capacity of approximately 15,000 cfm. Full operations required 28 people per shift. This new development obviously provided a tremendous increase in production.

During the transition period, involving the construction of the unit, providing the proper duct work, etc., there was a concurrent rapid increase in personnel to man the unit. A large number of new people had to be trained in the operation. For a period of about two months (September to November, 1955) there was a rapid appearance of respiratory complaints from people working near or with TDI. During this short period, 42 cases of respiratory irritation were ascribed to TDI exposures. Of these 42 cases, nine were serious enough to require hospitalization.

With the completion of the unit, the number of cases rapidly subsided. The hospitalized cases recovered with no residual effects, except in some cases, for a specific respiratory sensitivity to TDI vapor.

Our experience corroborates the findings of other observers, that the fumes of TDI can be irritating and capable of producing symptoms of varying degrees of severity in certain individuals. It appears that, in some cases, symptoms will develop on short exposure to high concentrations of the chemical, while in others the symptoms develop after prolonged exposure to low concentrations. We are convinced that when an individual becomes sensitized to TDI, there results an allergic state in which the threshold is lowered, so that symptoms appear again at progressively lower concentrations of TDI vapor.

Our air testing program began in March, 1955, several months after operations began. At that time, we obtained results by the cellosolve-nitrite method[6] indicating occasional exposures in excess of the standard tentatively adopted for TDI of 0.1 ppm. Later ventilation changes brought about a substantial reduction in this exposure. Further tests during the year on the modified equipment described in Figs. 1 and 2 showed results well below the permissible limit. In the transitional state, from stage two to stage three (see Fig. 3), adequate atmospheric testing was not carried out because of the numerous changes taking place. It is suspected that during the brief period during which respiratory difficulties were encountered, that is, September to November of 1955, that atmospheric concentrations of

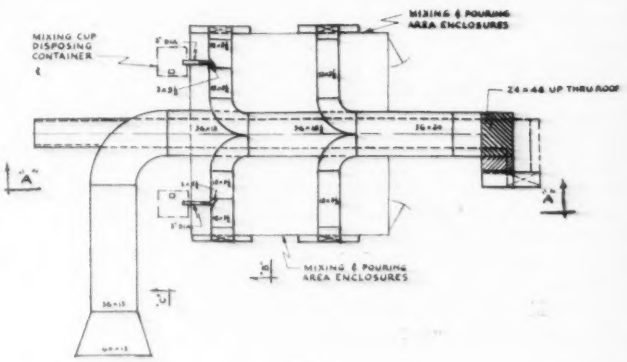

Fig. 3.
Plan below roof.

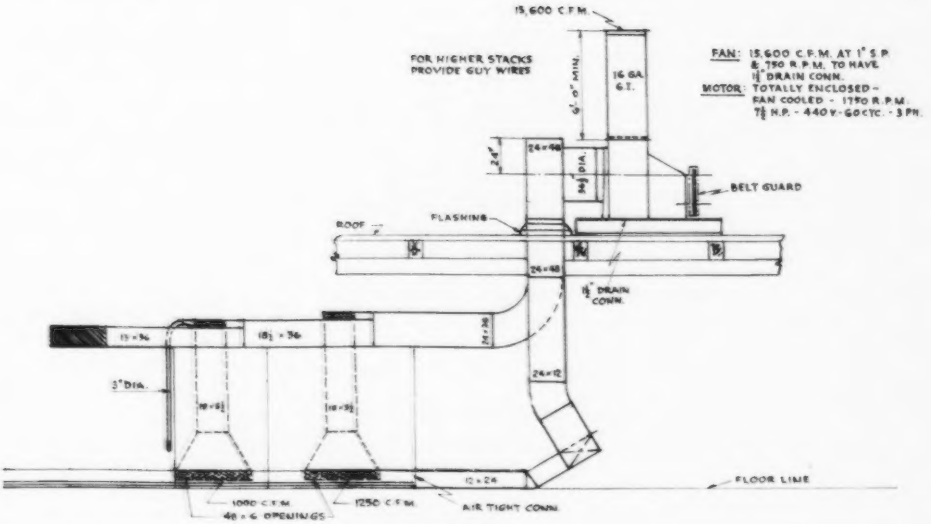

Fig. 4.
Section A-A.

TDI vapor may have been in excess of the permissible limit. Tests were carried out periodically after the completion of the newer units. These tests indicated that the average concentration was in the range of .04 to .06 ppm of TDI.

As we accumulated experience in handling TDI, we worked out a series of basic engineering and medical control measures, which are summarized below:

1. Adequate ventilation is essential. All operations involving vapor production should be enclosed. Downdraft ventilation is preferred. Average face velocity at booths should be a minimum of 200 ft/min.
2. Provision of outside humidified makeup air to balance the exhaust system.
3. Enclosure of mixing supply vessels to transport TDI from storage area to production area.
4. Provision of enclosed and ventilated scrap removal system.
5. Periodic maintenance check to insure proper operation of exhaust equipment.
6. Periodic air sampling.
7. Strict attention to housekeeping. Cleaning of spills and removal of all scrap is a very important control measure.
8. Provision of adequate protective equipment to operators, disposable paper aprons, gloves, and respiratory protection where necessary.
9. Medical controls consisting of: (a) An over-all pre-employment physical examination with special reference to past history of allergies, and respiratory conditions—chest x-ray. (b) Periodic examina-

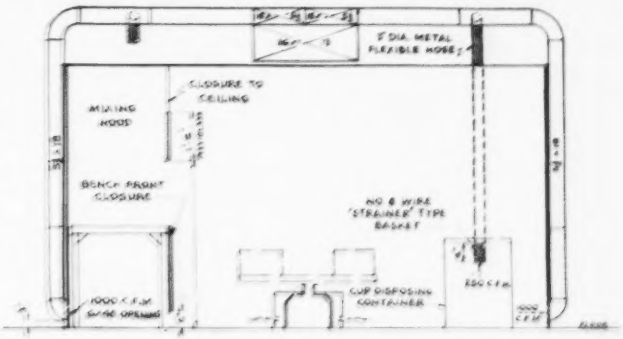

Fig. 6.
Section B-B.

tions of all employees exposed to TDI, with special attention to the respiratory system. (c) Complete physical examination on any employee who shows incipient signs of sensitization. (d) Removal of sensitized persons from TDI exposure.

Summary

IN SUMMARY, our experience indicates that the potential health problems in the use of TDI can be overcome provided that the problems are recognized, and provided that the elements of the engineering and medical control program, outlined above, are carried out.

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Graduate Courses in Environmental Hygiene

THE INSTITUTE of Industrial Health of the University of Cincinnati offers a formal two-year course to candidates who wish to pursue graduate training in the field of environmental hygiene, (industrial hygiene, air pollution, industrial wastes, toxicology, etc.). The Institute combines the facilities of the Kettering Laboratory, the Colleges of Engineering, Medicine, Law and Business Administration, as well as the staff and facilities of the technical laboratories of certain local industries and research organizations. The candidate should be a graduate of an approved school of engineering or science. Orientation or additional training in chemistry or sanitary engineering is preferred but not absolutely essential. A Master of Science Degree can be awarded after one year of training in residence and the submission of an acceptable dissertation. The Doctor of Science Degree may be given to those who, after the completion of the two-year course, spend an additional year in supervised training and present a thesis. Requests for information or application should be directed to: Institute of Industrial Health, The Kettering Laboratory, Eden and Bethesda Aves., Cincinnati 19, Ohio.

The Problem of Isolating the Noise-Susceptible Individual

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NOISE-SUSCEPTIBLE workers are those persons who suffer handicapping hearing losses more quickly than do their companions under equivalent noise exposure. These workers constitute the group from which claims for compensation are most likely to arise and for whom awards are likely to be greatest.

Limitations to current knowledge impede discovery of the noise-susceptible individual. For one thing, the nature of noise-susceptibility and of the mechanisms underlying it is obscure. Secondly, definitive methods for detecting proneness to acoustic trauma prior to job placement await refinement and definitive validation.

CONTEMPORARY concepts regarding the nature of noise-susceptibility are astonishingly confused and lacking in objective support. Two premises, in particular, are accepted relatively uncritically. The first is that some people have an almost pathological proneness to noise-damage. The second is that noise-susceptibility constitutes a relatively permanent defect of the individual who exhibits it.

Both premises should be questioned critically. To be sure, such questioning may confirm either or both. However, whether it does or not, the increased insight which must result will allow more confident programs in industrial audiology. Moreover, there is some reason to believe that one or both of the premises may need revision.

The assumption that some people are unusually noise-susceptible springs partly from the clinical observations of the otologist, partly from the word-of-mouth tradition of workers in heavy industry, and partly from statistical studies of the hearing losses encountered in noisy occupations. To elaborate, the physician sees some patients whose hearing has become markedly impaired in conjunction with either dramatic incidents of acoustic insult or prolonged exposure to strong sound. The judgment that other listeners would not have suffered so severe an impairment under like circumstances is often made. This judgment probably is right, but it usually rests heavily on anecdotal evidence unsupported by exact knowledge of the exposure involved. Likewise, as Guild[1] has often remarked, seasoned workers urge new men who complain of excessive tinnitus and temporary loss of hearing to seek quieter jobs before their "tin ears" are permanently damaged. Finally, audiometric studies of industrial populations reveal a substantial range of hearing losses. It is easy to presume that this spread is the product of differences in susceptibility to acoustic damage but, again, precise evidence on the nature and extent of exposure is usually lacking.

On the other side of the ledger is the often confirmed observation that hearing losses which are clearly attributable to noise are less severe and less frequent in military and industrial populations than orginally anticipated. World War II produced only a small fraction of the handicapping hearing losses which authorities had predicted. Likewise, Gardner's[2] early analysis of hearing in workers with long exposures to industrial noise is notable because of the minuteness of the average involvement and the slowness with which it appeared to have progressed when correction was made for effects of age. A sim-

Research on the CAFT test reported in this paper was supported by funds provided under contract AF(600)-630 with the USAF School of Aviation Medicine, Randolph Field, Texas.

ilar conclusion emerges from the recent report by the Z24-X-2 Subcommittee of the American Standards Association.[19] Correction for presbycusic effects yields net losses which average sharply less than the raw audiometric scores reveal.

The foregoing examples illustrate the evidence which has accumulated in support of the view that, typically, the human ear is relatively rugged and is resistant (but not impervious) to permanent damage from noise. Moreover, even the "tender ear" may have more resistance than is often supposed if noise-susceptibility is the lower end of a continuum which represents normal variability among people. The relative rareness, within the industrial population, of marked auditory impairments which cannot be attributed to aging or to aural pathologies supports such a view, since the alternative is to reason that uncontrolled selective factors almost completely eliminate noise-susceptible individuals from the industrial population. Certainly, it is time to re-examine contemporary opinions as to the incidence of noise-susceptibility and as to the auditory danger the susceptible person faces.

Consider next the premise that noise-susceptibility is a permanent proneness to auditory insult. Consider also the corrollary premise that a given individual either does or does not possess this proneness. These premises rest on the belief that differences in noise-susceptibility are the result of stable anatomical, physiological or pathological variations among people. It has been suggested, for example, that the shape of the canal leading to the eardrum is critical in this regard. It is reasoned that configurational variations influence the sound pressure which occurs at the eardrum and, hence, a particular sound field may be safe for one person yet may damage a second person whose canal has different physical dimensions. Another idea has been proposed by Nesswetha.[10] He claims to have accumulated sufficient evidence of concomitant defects in vision and in hearing to allow the conclusion that some individuals possess a constitutional weakness which encompasses not only the ear but also other sensory organs. Such individuals are, presumptively, more easily harmed by noise. The important point at the moment, however, is that Nesswetha's view illustrates the concept that noise-susceptibility is a relatively permanent condition.

Interestingly enough, strong support can be amassed for an antithetical concept, namely, that individuals fluctuate in their proneness to acoustic trauma. Larsen,[6] almost 20 years ago, claimed there is extra danger in exposing workers with identifiable ear pathology to strong sound. Cook[1] suggested that an ear which is in electrolytic imbalance acquires increased vulnerability to noise. If such views are correct, noise-susceptibility must fluctuate in the ear with variable hearing loss of the end-organ variety. Moreover, one might also expect that sub-clinical changes in inner ear state would produce temporary differences in noise-susceptibility. Indirect evidence bearing on this possibility is to be found in the fact that fatigability and adaptation of the normal human ear can be modified by drugs. Willemse[17] and Ruedi[12] found that vitamin A increased tolerance for strong sounds. Tanner[15] noted that adaptation, which he feels is a protective mechanism reducing fatigability, was markedly changed by parasympathicolytic and sympathicolytic drugs.

Chance observations also support the view that noise-susceptibility may be a temporary phenomenon. For example, an experimental subject at Northwestern University failed to recover normally after a moderately fatiguing sound exposure. He proved to have a mild endolymphatic hydrops. Another subject maintains a heavy salycilate intake. He shows excessive temporary fatigue and highly unstable threshold levels. One must, when he observes cases with these peculiarities, conclude with Ruedi,[13] who feels that proneness to acoustic trauma is affected by general bodily health, that metabolic states within the inner ear probably modify the resistance of the auditory system to intense sound.

Such a possibility has tremendous implications for industrial medicine because it demands a radical modification in the procedures for dealing with noise-susceptibility. If proneness to auditory insult *varies* with physical state, then one must discard the comfortable assumption that acoustic vulnerability is a stable condition whose discovery awaits our convenience. One must

question the philosophy which presumes to catalogue a worker's noise-susceptibility definitively through a single test. One must face up to the possibility that any worker might enter a period of acoustic vulnerability as a result of illness, modification in physiological balance, increased age, medication, generalized fatigue, or dissipation. It is not precisely in jest that one wonders whether proneness to noise damage could properly be labeled "Monday morning malady."

In terminating discussion on this point, two statements must be made. The first is that intensive research is needed to determine the degree to which noise-susceptibility in industrial workers is a transient phenomenon. The second is that, pending such research, industrial medicine must accommodate its thinking and planning to the prospect that the measures which it institutes to protect the noise-susceptible worker should be of a type which allows continuing surveillance of all who work in environments of intense sound. One challenge is the necessity to evolve practical measures for achieving such surveillance.

IRRESPECTIVE of whether proneness to acoustic insult is a temporary or a permanent state, there is real necessity for definitive tests to identify the condition.

Industrial medicine is currently forced to expose workers to noise first, and, in due time, to pick out those who suffer excessive changes in hearing. This procedure is really empirical hindsight. Its basic feature is diagrammed in Fig. 1. At the left of the figure are five manikins. Each represents a new employee. Imagine that the white-headed manikin is noise-susceptible. He is a risk who should be assigned at the outset to a quiet working situation. Since he is not identifiable at the time of employment, however, he is likely to be sent to a noisy work area. The noise-susceptible worker is later found because his hearing begins to be damaged relatively quickly and severely. Once he is discovered, this worker may, of course, be placed in a quieter situation. However, the damage already done may make him a potential claimant for compensation.

A commonly proposed solution to the present "wait-and-see" method for discover-

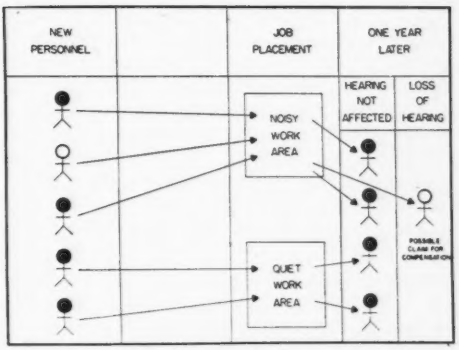

Fig. 1.
Diagram illustrating the outcome of unwittingly assigning noise-susceptible person, represented by white-headed manikin, to job in noisy job area. (Prepared by James F. Jerger)

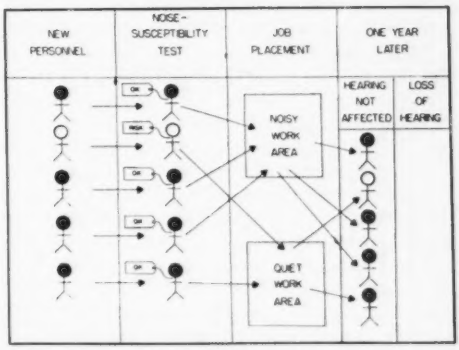

Fig. 2.
Diagram illustrating manner in which an effective test for noise-susceptibility can facilitate protection of the worker, represented by the white-headed manikin, who is prone to acoustic trauma. (Prepared by James F. Jerger)

ing noise-susceptibility is diagrammed in Fig. 2. The theory is that each new worker is to be given a noise-susceptibility test at the outset of employment. The test locates the worker who is the auditory risk, and he can be assigned to a quiet work area immediately. In consequence, his hearing is effectively conserved.

Such a solution is greatly to be desired if it can be made practical and demonstrably accurate. The initial problem, of course, is to find a fully valid test of noise-susceptibility. Such a test, as Wheeler[16] has pointed

out, must be completely dependable. It must also be simple and rapidly administered. Thus, the search for a good test breaks down into two sub-problems. First, one must find an auditory function which is irrevocably bound in some way to noise-susceptibility. Second, one must devise a reliable, a quick, and an uncomplicated method for measuring this function.

Temporary threshold shift has been the most popular of the several auditory phenomena which have been proposed as indicators of noise-susceptibility. The rationale here is the assumption that ears which are easily damaged by noise also show their weakness in rapid and extensive "fatigability." Stated operationally, the belief is that when such ears are exposed to intense sounds of limited duration, their transitory impairment in acuity is greater and their recovery is slower than normal.

Numerous investigators[3,11,14,18] have developed procedures for measuring either the temporary threshold shift induced by a standardized noise or the rapidity of recovery from this exposure. These investigators have not agreed on such details as the frequency whose threshold shift is to be measured, whether threshold should be probed with a continuous or a pulsing tone, what type of sound should be used as the fatiguing stimulus, and at what level this sound should be presented to the ear. Moreover, some of the proposed techniques have measured auditory adaptation, while others induce a fatigue phenomenon proper. A somewhat chaotic situation is the inevitable result of the lack of agreement on methodology.

Fortunately, however, research has yielded sufficient information so that simple and rapid tests of temporary threshold shift can be devised. One such test, known as the CAFT,[5] has been developed at Northwestern University. The procedure of the test is easy. Each ear is explored independently. The subject first finds his threshold for a pulsed tone of 4500 cps. He is then exposed for a minute to a 3000 cps tone at 100 db SPL, following which the pulsed tone returns to a level 20 db stronger than the original threshold. Simultaneously, two chronometers are started. The subject will again hear the pulsing tone as soon as he has recovered to within 20 db of his original threshold. When this occurs, he presses a lever that stops one chronometer and reduces the pulsing signal by 10 db. The subject presses another lever when this fainter signal becomes audible, thus stopping the second chronometer. The two chronometers record the time required to return to within 20 and 10 db of the original threshold, respectively. These two measures of elapsed time give a simplified representation of the recovery curve for the ear under test.

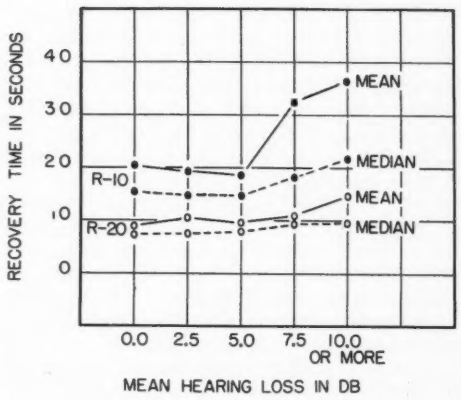

Fig. 3.
Results of administering the CAFT test to students entering a 12-week course for jet mechanics. R-20 is recovery to within 20 db of the pre-CAFT threshold for 4500 cps, while R-10 is recovery to within 10 db. Mean hearing loss is the average for 3000 and 4000 cps. It represents the audiometric deterioration, re their pre-training hearing levels, exhibited by the various students at the termination of their course. (345 ears)

The CAFT test was administered to an incoming class at an Air Force school for jet mechanics. Recovery time, by CAFT, was measured on 345 ears prior to their exposure to jet engine noise. This exposure totaled 12 hours. Audiograms were obtained before exposure and at the end of the training course. Results, as illustrated in Fig. 3, indicated that the men who retained slight losses, eight weeks after exposure tended to have recovery times on the pre-exposure CAFT test which were greater than were the recovery times for the ears with no change.

Such findings add confidence to the belief that measurement of temporary threshold shift holds promise as a key to noise-sus-

ceptibility. However, definitive validational evidence must be procured before this belief can be accepted with any finality whatsoever.

A second auditory function has been vigorously advocated as a clue to the identification of noise-susceptibility. It is the phenomenon of aural overload. To explain, when the inner ear is activated by a sinusoidal sound (pure tone), it adds overtones within itself if it is driven strongly enough to produce distortion of the signal. This distortion signifies the occurrence of aural overload. It may be discovered by introducing into the ear a second tone which beats with the induced overtone. The subject then hears an audible flutter.

Lawrence and his associates have pioneered in developing the clinical procedure for determining aural overload. He and Yantis[8] have accumulated evidence to show that inner ear pathologies are characterized by the appearance of the overload phenomenon at intensities close to the threshold of audibility. He and Blanchard[7] have expressed the view that the ear which overloads early damages easily. Presumptively, such early overload should be measurable in the noise-susceptible ear with normal acuity. One must be cautious, however, in his optimism regarding the practicality of the aural overload test. The judgment required of the subject, namely, listening for a faint flutter against a background of steady tone, is relatively difficult to make. It is doubtful whether the rank and file of industrial workers can perform this judgment quickly enough and reliably enough to allow a rapid version of the aural overload test to be employed with satisfying success. Certainly, the experience at Northwestern University has been that an aural overload test is a fully usable clinical technique, but that even sophisticated listeners must sometimes have substantial instruction before they are clear on the judgment they must make. Unfortunately, errors which occur tend to be those in which the overload is not perceived at as faint a level as it should be. Mistakes of this type miss the very clue which, presumably, indicates noise-susceptibility.

A further difficulty which one dare not take lightly is the fact that extremely fine apparatus is required for an overload test. This is true because distortion in the equipment can be mistaken for distortion in the subject's ear. Not only must the equipment for overload testing be of exceptionally fine design and of proved performance, but it must also be maintained meticulously.

Brief mention should be made of a third phenomenon which has been proposed as a criterion of proneness to noise damage. This phenomenon is the cumulative shift in auditory sensitivity induced by successive auditory insult of mild degree. The rationale here is obvious if one reasons from the presumption that the early damaged ear tends to pile up the effects of successive insults more completely than does the sound-resistant ear.

Most methods which aim at measuring temporary threshold shift can be adapted to a cumulative procedure. The CAFT test, for example, can be administered to the same ear three times in quick succession, and the progressive elongation of recovery time can be taken as the measure of cumulative effect. Individual differences in cumulative effect stand out sharply when this is done. Here, then, is a modification of the CAFT procedure which appears most useful. It could well be that this procedure, or some other measure of cumulative effects, would provide a satisfactory combination of validity and practicality in the search for the noise-susceptible person.

As a final point, one must remember that a definitive relation between noise-susceptibility and any single auditory function has never been demonstrated. It may be that one of the functions discussed in this paper will prove to have such a relation when explored with the proper methodology. On the other hand, some other function may ultimately prove to be the indicator which is being sought. The third possibility is that no facet of hearing behavior is intimately enough associated with proneness to auditory insult so that it can serve as a sure criterion of such proneness. If this last be the case, of course, the search for a test of noise-susceptibility is futile.

One thing is certain even though we cannot be sure what the outcome will be in the present efforts to find a test for noise-susceptibility. Extensive research must be continued if industrial audiology is to understand and to cope fully with the problem of isolating the noise-susceptible person.

IN SUMMARY, the task of finding the noise-susceptible worker is complicated by imperfect knowledge regarding the nature and the relative incidence of proneness to acoustic trauma. It is not clearly established to what degree this susceptibility is a continuing predisposition and to what degree it is transiently induced by temporary metabolic or biochemical states. Several test procedures have been proposed as tools for discovering workers with predisposition for noise-damage. Among these are the methods for measuring temporary threshold shift, threshold for aural overload, and reaction to cumulative auditory stimulation. Final judgment on each procedure must await field validation.

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Award to Past President

DR. ALLEN D. BRANDT, Chief Industrial Hygiene Engineer, Bethlehem Steel Company, and Past-President of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION has received an award from the Association of Iron and Steel Engineers for authorship of a paper entitled "Are You Getting Good Returns from Your Ventilating Investment?" The AISE gives annual awards to authors of papers of value in the advancement of engineering or operating practice in the iron and steel industry. Dr. Brandt's paper was published in *Iron and Steel Engineering*.

NEW DEVELOPMENTS IN

Dispersion Staining Microscopy as Applied to Industrial Hygiene

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A NUMBER of papers have been published on the use of dispersion staining microscopy[1, 2, 3,4] for the identification of dusts. Detailed information concerning the optics of this method have been described in these previous publications. This paper is concerned mainly with new investigations concerning equipment, high dispersion mounting media, sample collection and the possible use of this technique for the examination of microincinerated specimens.

Equipment

A NUMBER of combinations of objectives and condensers can be used for dispersion staining microscopy. However, the best available equipment for the identification of small particle size dust appears to be a combination of a 20x (0.40 N.A.) objective with a 0.59 N.A. achromatic condenser designed for use in a simple rack and pinion substage. The numerical aperture of 0.59 is obtained by removing the top element from a 1.40 N.A. achromatic condenser. This difference (0.19) in N.A. between condenser and objective gives strong identifying dispersion colors. Weak dispersion colors are obtained when the difference in numerical aperture is considerably less or considerably greater than 0.19.

As indicated in previous publications, difficulty may be encountered in obtaining a dark-field stop of 17 mm in diameter for use below the 0.59 N.A. condenser. As a substitute, a dime (approximately 18 mm in diameter) can be used with fair results if a suitable support for the dime can be obtained. If one is fortunate to have a 16 mm stop as furnished for many years with new microscopes, that size stop can be used as a support. The dime should be centered to the smaller stop and cemented in place. It must be accurately centered in the substage holder. This can be accomplished by trial and error or more rapidly by use of a telescope such as furnished with phase microscopes for centering the image of the substage annulus with the objective annulus.

If a smaller stop is not available, the dime can be cemented to a disc 33 mm in diameter stamped out of lucite (thickness 1/16 inch) or a 17 mm stop can be painted directly on the lucite using a black lacquer. If the 0.59 N.A. condenser is not to be used for other purposes, the dark-field stop can be painted directly on the lower surface of the condenser. At that location, some experimentation would be necessary in order to determine the exact diameter giving the best results.

In the case of particulate material less than one micron in size there is a need for higher magnification than possible with the 20x (0.40 N.A.) objective. As reported in previous publications, higher magnifications can be obtained by use of a 4 mm (0.65 N.A.) objective in combination with the 0.59 N.A. condenser but the N.A. of the objective must be reduced by insertion of a funnel stop. Use of a stop is objectionable since it must be very accurately centered and of a length as to touch the back lens of the objective. Another objection is the fact that use of a funnel stop reduces the N.A. of the objective and thus its resolution.

In an endeavor to overcome this problem, a 4 mm objective measuring 0.65 N.A. on an apertometer was used without a funnel stop in combination with a 0.70 N.A. Abbe condenser. Due to the proximity in numerical

aperture of the objective and condenser, it was necessary to use a dark-field stop 22 mm in diameter (largest size available) below the condenser. Even this size was not totally effective in blocking out the central rays of light which is necessary for the identification by dispersion colors of small particle size material. Although this combination of objective and condenser cannot be recommended for use, the results of this experimentation suggest that if either a condenser of slightly higher N.A. could be obtained or an objective of slightly lower N.A., equipment would be available for the identification of smaller particle size than possible with the 20x (0.40 N.A.) objective.

High Dispersion Mounting Media

Success with dispersion staining depends not only on correct numerical aperture difference between objective and condenser but also on the use of mounting media of greater dispersion than the sample. In general, organic index liquids commonly employed have steeper dispersion curves than the particulate material examined. High index liquids are usually of high dispersion giving brilliant dispersion colors. However, many particulate materials encountered, such as tridymite and cristobalite, are in the low index range and the dispersion colors obtained with low index immersion liquids of low dispersion such as used for the Becke line method of identification are at times too weak in coloration for accurate identification of small particle size. The use of cinnamic aldehyde with butyl carbitol as suggested in previous publications gives strong dispersion colors in the low index range due to the high dispersion of cinnamic aldehyde. Unfortunately, mixtures of butyl carbitol with cinnamic aldehyde in a short time change in index due to the breakdown of cinnamic aldehyde to cinnamic acid.

Due to the instability of cinnamic aldehyde an attempt was made to find a substitute. It was found that ethyl cinnamate (Eastman Kodak Co.) having a refractive index of 1.557 and a mean dispersion of 0.028 formed a more stable mixture with butyl carbitol and was thus suitable for an index range of approximately 1.428 to 1.557. For a range of 1.557 to 1.625, ethyl cinnamate can be mixed with aroclor 1242 and from 1.625 to 1.655, aroclor with alpha-bromonaphthalene. If higher indices are necessary, alpha-bromonaphthalene can be mixed with methylene iodide to give indices up to approximately 1.73. Saturation of the methylene iodide with sulfur will give a maximum index of 1.78+. Still higher indices up to an index of approximately 2.00 are now possible as a result of the investigations of Meyrowitz and Larsen[7] using mixtures of sulfur, arsenic tribromide and arsenic disulfide.

During the investigation for a high dispersion substitute for cinnamic aldehyde, it was noted that styrene (Eastman Kodak Co.) refractive index 1.543 - 1.544 had a high dispersion. Styrene on exposure to light or air will gradually polymerize but the Eastman Kodak product stabilized with tert-butylcatechol has maintained a constant refractive index for over a year. For accurate results, it is best to check the dispersion colors obtained with the styrene used against material known to be quartz. Although styrene is not ideal for index mixtures with butyl carbitol due to its higher vapor pressure, it has proved to be of definite value for the identification of quartz, having the same refractive index as the ordinary ray (1.544) of this dust. Small size quartz particles mounted in styrene and oriented for the 1.544 index as observed with a cap analyzer over the eyepiece of the microscope appear primarily a dark blue. In the case of large particle size a trace of red is also perceptible. Particles oriented for the 1.553 index appear either blue with a large amount of red or entirely red dependent on their particle size. If there is no objection to the odor and possible toxicity in the small amounts used for mounting preparations, the use of styrene for the identification of quartz is preferable to a mixture of butyl carbitol and ethyl cinnamate since use of a refractometer for adjustment of the refractive index is not necessary.

If an index liquid such as styrene cannot be found equal in refractive index to the dust in question, it is possible to use a liquid slightly higher in index. This technique is based on the principle that as the temperature increases the index of a liquid decreases. For example, ethyl cinnamate has a refractive index of approximately 1.557 at 25°C (77°F) which is four in the third decimal place higher than the extraordinary

ray (1.553) of quartz. At that temperature, quartz particles oriented for the ordinary ray (1.544) appear light blue, particles oriented for the extraordinary ray (1.553), a dark blue. If now the preparation is placed on a hot stage and the temperature increased, it will be found that as the temperature rises, quartz particles change to a red coloration followed by a gradual transition to orange, yellow and finally white as the temperature is further increased. Notation of the temperature at which a certain color is obtained can be used as a method of identification.

Collection of Sample

ALTHOUGH samples can be collected for examination by dispersion staining by the usual methods such as electric or thermal precipitation and filtration methods including the use of a molecular filter, our experience has been mainly the collection in midget impingers in isopropyl alcohol. It is, of course, necessary to collect long enough to obtain an adequate sample for microscopic examination. Since that length of time may result in evaporation of the collecting liquid, it is usually necessary before total evaporation to add additional liquid to the impinger. When an appreciable sample is obtained as evidenced by cloudiness of the liquid, sampling can be discontinued. The collecting liquid is poured from the impinger into a small pyrex beaker of 10-20 ml capacity as used in micro-chemical analysis and slowly evaporated to dryness. Portions of the dry dust can be scraped from the bottom of the beaker and examined in the high dispersion liquids described above for the presence of identifying dispersion colors.

It is very important for optimum results (maximum brilliance of color) that the slide and coverglass be clean as examined by dark-field inspection. Cleaning slides and coverglasses with Bon Ami and wiping with lens paper usually gives good results.

It is sometimes possible to use the identifying liquid as the collecting medium providing the two constituents of the index liquid are quite close in vapor pressure. For example, in the case of dust counts taken in a foundry where determination of the percentage of quartz is necessary, 10 ml of a mixture of butyl carbitol with ethyl cinnamate adjusted to an index of 1.542 - 1.544 can be used as the collecting liquid in place of the usual distilled water or alcohol. After making the dust count by either bright-field or phase microscopy[5] using an all glass hemacytometer as the counting chamber, the accessory equipment suggested above for examination by dispersion staining can be substituted. Using this equipment the same preparation can now be examined for the approximate percentage of free silica quartz. It is usually desirable to use an index liquid adjusted to an index of approximately 1.542 rather than 1.544. Using that index in conjunction with a cap analyzer placed over the eyepiece, a brighter red color is obtained in the case of particles of quartz oriented for the 1.553 index (extraordinary ray of quartz) which enhances their contrast on the dark background.

Microincineration

IT WAS BELIEVED that dispersion staining using the dark-field microscope might be of some value for the examination of microincinerated microtome sections. This belief was substantiated by the fact that Einbrodt[6] using dispersion staining with the phase contrast microscope[1] and solid mounting medium of index 1.553 was able to distinguish quartz from mica and kaolin in lung dust isolated by the formamide technique. To try out this supposition, pieces of silicotic lung preserved in formaldehyde were obtained from Carborundum Company and microtome sections of silicotic lung from Saranac Laboratory. The method of microincineration used was similar to that described by G. H. Scott in the chapter, "Microincineration Methods for Demonstrating Mineral Elements in Tissue," *Handbook of Microscopical Technique* by Ruth McClung Jones.

Following incineration the preparations were mounted under a coverglass in either styrene or a 1.542 mixture of butyl carbitol with ethyl cinnamate. Particles which changed in color from blue to red or the reverse as the cap analyzer was rotated 90 degrees were identified as quartz. Particles identified as quartz were mainly 1-3 microns in size.

Although the method is very accurate for the positive identification of quartz parti-

cles in tissue, difficulty was encountered in seeing small particle size quartz in color in thick microincinerated sections especially when quartz particles were overlaid with ash of high enough index to appear white. Some improvement of this difficulty should result, if as indicated in this publication, microscope equipment of higher magnification and resolution becomes available for dispersion staining microscopy.

Acknowledgement

THE AUTHOR wishes to thank George Eddy, M. D. of Carborundum Company and Thomas Durkan of The Saranac Laboratory for furnishing samples of human silicotic tissue for this preliminary investigation as to the possible use of dispersion staining microscopy for examination of microincinerated specimens; also R. Robert, P. Watts and G. Nielsen of this laboratory for their assistance with the technical work necessary for carrying out this investigation.

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Important Notice to All Subscribers

SEVERAL changes will be made at the end of 1957 which will affect subscriptions to the *AIHA Quarterly*. The journal will be published six times a year by the Williams and Wilkins Company of Baltimore. The name of the journal will be changed to the *American Industrial Hygiene Association Journal*. Members of AIHA will continue to receive the journal as one of the benefits of membership. Associate members may subscribe through the Secretary of the local section at a special rate. The annual subscription price in the United States starting January, 1958, will be $7.50. The Canadian subscription will be $7.75 and all other foreign subscriptions will be $8.25. Subscriptions will be sold on a calendar year basis and will not be allowed to start in the middle of a volume. Orders for 1958 should be addressed to *AIHA Journal*, % Williams and Wilkins Co., Mount Royal and Guilford Avenues, Baltimore 2, Maryland.

Evaluation of Potential Health Hazards in

Fumigation of Shelled Corn with a Mixture of Carbon Disulfide and Carbon Tetrachloride

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THE PRESERVATION of surplus agricultural products has resulted in potential occupational health hazards to numerous workers. An example is the storage of shelled corn purchased by the Federal government under its price support program, which included approximately 747 million bushels as of January 31, 1956. To protect the corn from spoilage, periodic inspections are made for evidence of infestation by grain pests, and the corn is fumigated when such evidence is found. In the 1956 season, the fumigant most commonly used on stored shelled corn was known as Grain Fumigant #3, consisting of 80% carbon tetrachloride (CCl_4), and 20% carbon disulfide (CS_2) by volume.

A study of the potential health hazards involved in the fumigation of shelled corn in storage bins, and in the subsequent inspection of the fumigated corn, was made in the summer of 1956 by the Occupational Health Program, at the request of the Commodity Stabilization Service, U.S. Department of Agriculture. The study was limited geographically to the 23 counties in the southwestern part of Ohio and, although this paper is based on the findings in these counties, the results may be reasonably projected to the entire program, as the operations are essentially similar.

Throughout the corn belt of the United States, there are approximately 4500 bin-sites with an average of about 40 bins per site. In Ohio, where this study was conducted, there are approximately 5800 bins located on 123 bin-sites. For each county a bin-site supervisor and crew are employed to handle the day-to-day operations of accepting shelled corn from the farmers, filling the bins, periodically inspecting the corn, fumigating the grain when infested, and removing the stored corn for disposal. The bin-site personnel are encouraged to seek the assistance of a full-time state crew to do the fumigating, and an increasing number are resorting to this assistance. In Ohio, the state crew performed about 50% of the fumigations during the 1956 season.

Most of the corn is stored in cylindrical steel or aluminum bins 12 feet in diameter, and 12 to 18 feet tall. Other types of storage facilities include quonset huts, concrete silos, and rectangular wooden buildings. Bin-sites may have as few as 10 bins, or as many as several hundred bins, and three or four quonset huts. An 18-foot cylindrical bin has a capacity of about 3,500 bushels of shelled corn and a quonset hut, 25,000 bushels.

In fumigating corn in a storage bin a man stands on a ladder at the top of the bin and sprays the grain with liquid fumigant through an open hatch (Fig. 1). About 18 gallons of fumigant are sprayed into an 18-foot bin, at the rate of three to four and a half gallons per minute. In a quonset hut, the fumigator walks to the far end of the building, and sprays as he

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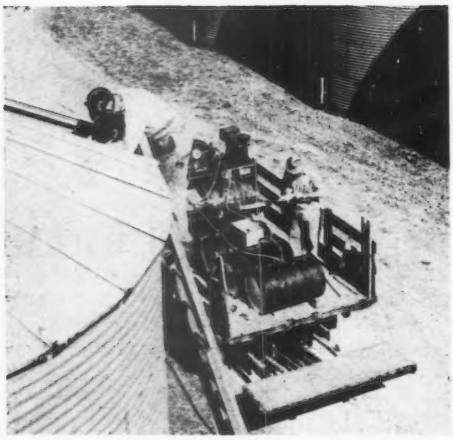

Fig. 1.
Full-time fumigation crew at work. Two pumps and metering equipment were permanently mounted on the truck. The truck moves along the row of bins, which are fumigated in turn, usually two at a time. This crew often fumigated 40 such bins in a working day.

retreats to the door. He spends about 35 minutes to one hour in this procedure, and uses about 100 gallons of fumigant.

Full-face gas masks with organic vapor canisters are available to all fumigation crews. In general, the men doing the fumigation wear the masks, but the men tending the pump and fumigant barrels do not. The men are instructed to leave the area if they smell organic vapors through the mask, which might be caused by an improperly fitted mask or an exhausted or defective canister. The canisters most often used are effective in atmospheres containing up to 2% organic solvent vapor for a period of half an hour at this concentration, or an equivalent time-concentration value.

Members of the bin-site crews have been instructed not to enter fumigated bins for three days after the fumigation; thereafter they enter, usually without a mask, to inspect for insect kill and to rake the surface corn.

Environmental Study

THE STUDY was conducted with the full cooperation and assistance of Commodity Stabilization Service employees of the U.S. Department of Agriculture, including members of the State of Ohio Agricultural Stabilization and Conservation (ASC) Committee and staff, the different county ASC Committees and staffs, state fumigation crew, county bin-site crews, and the district grain storage supervisors.

Included in the study were the State of Ohio fumigation crew and certain county bin-site crews. The state crew, consisting of four men, fumigated shelled corn full-time from approximately July through October. Their procedures were observed, and air samples of fumigant vapors were taken at six different bin-sites during the study. The operations of bin-site crews while fumigating corn were studied in five counties. Follow-up air sampling of the vapor residue was done in nine counties where the bin-site employees were potentially exposed to solvent vapors while inspecting the corn after fumigation.

Fig. 2.
Halide meter with by-pass adaptation attached. The air sampled was split between the organic vapor canister and the rotameter by-pass.

FUMIGANT VAPOR DETERMINATIONS: Air analyses were made for CCl_4 and CS_2 only, since as previously stated, the fumigant consisted essentially of 80% CCl_4 and 20% CS_2 by volume. CCl_4 was determined by two techniques: (1) adsorption on silica gel, with subsequent combustion of the vapor and analysis by Mohr's titration,[1] and (2) the use of the Davis Halide Meter. Seven samples were collected and analyzed

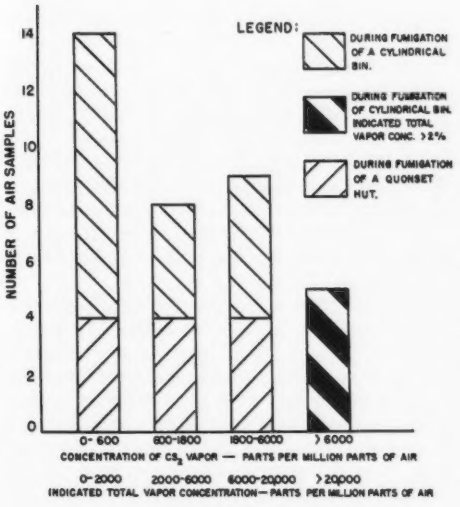
LEGEND:
DURING FUMIGATION OF A CYLINDRICAL BIN.
DURING FUMIGATION OF CYLINDRICAL BIN, INDICATED TOTAL VAPOR CONC. >2%
DURING FUMIGATION OF A QUONSET HUT.
NUMBER OF AIR SAMPLES
0 2 4 6 8 10 12 14
0-600 600-1800 1800-6000 >6000
CONCENTRATION OF CS_2 VAPOR — PARTS PER MILLION PARTS OF AIR
0-2000 2000-6000 6000-20,000 >20,000
INDICATED TOTAL VAPOR CONCENTRATION — PARTS PER MILLION PARTS OF AIR

Fig. 3.
Carbon disulfide vapor concentrations taken during fumigation at canister inlet of crew members wearing gas masks.

by the former technique, while numerous readings were made with the halide meter. A full-scale deflection on the Davis instrument corresponds roughly to 300 ppm CCl_4; for higher concentrations, a homemade by-pass attachment was constructed (Fig. 2). This device splits the flow from the sampling probe into two streams, one passing unaffected through a rotameter, while the main stream passes through an organic vapor gas mask canister. The two streams are then reunited and fed into the instrument. With this arrangement, the instrument could measure concentrations of CCl_4 in the air from 200 to approximately 60,000 ppm.

Carbon disulfide vapor in the air was determined colorimetrically using a diethylamine-copper reagent in alcoholic solution.[2] Concentrations up to about 300 ppm were sampled with a midget fritted bubbler using the color reagent as the collecting medium, and a midget impinger pump as the source of suction.[3] Higher concentrations were sampled with 150-cc grab sample flasks, which were then injected with the color reagent by means of a hypodermic syringe.

The working population was classified into three groups dictated by the type of exposure they received. These were:

1. Spraying fumigant — these men generally wore masks.

2. Tending fumigant pump and barrels — masks were not generally worn by this group.

3. Inspecting corn after fumigation — masks were not worn.

Samples were taken for CCl_4 and CS_2 at each of the above operations, and, where possible, simultaneous samples were collected. Results of analyses of simultaneous samples indicated that the ratio of CCl_4 to CS_2 vapors averaged 2.5 during the fumigation process. Since the readings of the halide meter usually varied widely during fumigation, it was difficult to express the CCl_4 concentrations except as a range of values. For this reason CS_2 concentration values alone are shown in Figs. 3 and 4, and in the discussion of results. Indicated values of CCl_4 using the 2.5 ratio are also shown. It should be understood that if 100 ppm of CS_2 is determined to be present during fumigation, approximately 250 ppm CCl_4 is also present. On the other hand, the readings of the halide meter were constant when tests

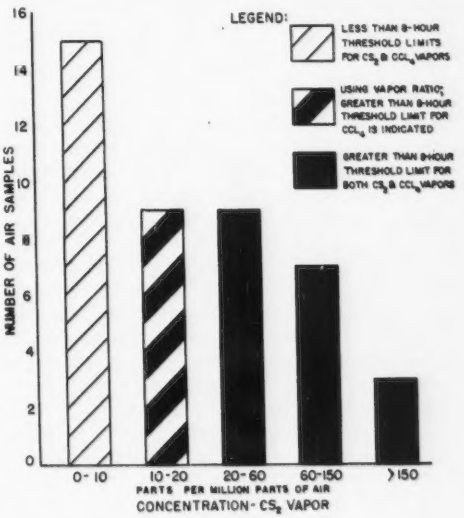
LEGEND:
LESS THAN 8-HOUR THRESHOLD LIMITS FOR CS_2 & CCl_4 VAPORS
USING VAPOR RATIO, GREATER THAN 8-HOUR THRESHOLD LIMIT FOR CCl_4 IS INDICATED
GREATER THAN 8-HOUR THRESHOLD LIMIT FOR BOTH CS_2 & CCl_4 VAPORS
NUMBER OF AIR SAMPLES
0 2 4 6 8 10 12 14 16
0-10 10-20 20-60 60-150 >150
PARTS PER MILLION PARTS OF AIR
CONCENTRATION - CS_2 VAPOR

Fig. 4.
Carbon disulfide vapor concentrations taken during fumigation at breathing zones of crew members not wearing gas masks.

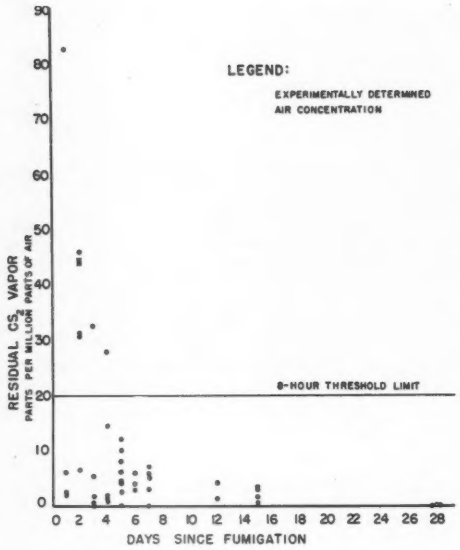
LEGEND:
EXPERIMENTALLY DETERMINED AIR CONCENTRATION
8-HOUR THRESHOLD LIMIT
RESIDUAL CS_2 VAPOR PARTS PER MILLION PARTS OF AIR
DAYS SINCE FUMIGATION

Fig. 5.
Follow-up air samples for carbon disulfide vapor.

were made in the bins after fumigation. These readings were made simultaneously with the collection of the CS_2 samples, and the results are shown in Figs. 5 and 6.

The first group of CS_2 and CCl_4 vapor samples was taken to ascertain whether the canisters were being depended upon for complete protection in concentrations greater than their specified upper limit. All samples in this group were taken during the fumigation of bins, quonset huts, and other buildings, by both the state and county crews. Fig. 3 shows that five of 36 samples exceeded 6,000 ppm of CS_2 which indicates a total vapor concentration of over 20,000 ppm for CS_2 and CCl_4. This latter value is above the safe limit for the canister. The five excessive concentrations were found during the fumigation of 18-foot cylindrical bins. In this operation, especially in the absence of a strong breeze, heavy vapors tend to be displaced through the open hatch and roll down the side of the bin, generally in the path of the fumigator. This vapor stream is often sufficiently concentrated to impart a cooling sensation on parts of the body which it contacts. Since the canisters are generally worn on the chest below the mask, air is usually drawn from the heaviest concentrations.

All of the samples taken while corn was being fumigated in quonset huts were below 2,500 ppm CS_2, or a combined CCl_4-CS_2 vapor concentration of approximately 8,750 ppm. This value is well within the 2% limit of the canister, but, owing to the length of time required to fumigate corn in a quonset hut (35 min.-1 hr.), a fresh canister should be used if one fumigator does the entire job.

One member of each fumigation crew spends most of his time tending the pump, opening barrels, metering the fumigant, and at other miscellaneous duties. Breathing zone samples for such crew members varied from 0 to 7,700 ppm of CS_2, and 0 to an indicated value of 19,000 ppm of CCl_4.

The calculation of weighted exposures for these men is rendered extremely difficult by the great variations in both concentrations and durations of exposures. Concentrations are relatively low much of the time, making the continuous wearing of gas-masks an unduly arduous requirement. Severity of exposures could be materially reduced if the workmen could locate the equipment upwind from the bin being fumigated.

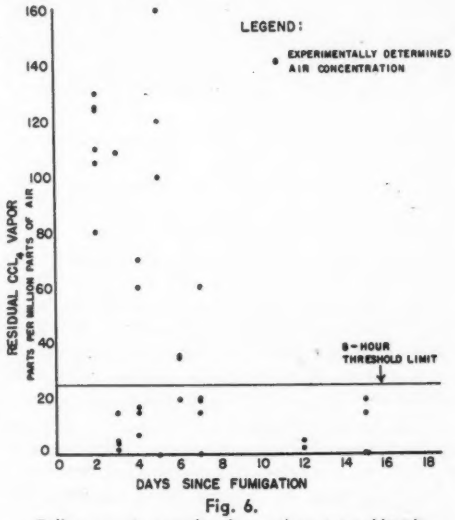
LEGEND:
EXPERIMENTALLY DETERMINED AIR CONCENTRATION
8-HOUR THRESHOLD LIMIT
RESIDUAL CCl_4 VAPOR PARTS PER MILLION PARTS OF AIR
DAYS SINCE FUMIGATION

Fig. 6.
Follow-up air samples for carbon tetrachloride vapor.

The second group of samples was collected during fumigation operations such as those just discussed, where the men did not use respiratory protection. The results of these breathing zone samples for CS_2 are shown in Fig. 4. Nineteen, or 45% of the 42 samples collected were above the threshold limit of 20 ppm. Likewise, the halide meter readings indicated that the threshold limit of 25 ppm for CCl_4 was exceeded at many sampling locations.

The third group of samples was taken to determine the potential exposure of the county bin-site employees who enter the bins to make routine tests on the corn after fumigation. Figs. 5 and 6 represent time-concentration plots of air samples for CS_2 and CCl_4 taken during these inspection operations. Carbon disulfide concentrations in the bins studied were below the threshold limit value five days after fumigation. On the other hand concentrations of CCl_4 near or above the threshold value were found after seven days. The wide range of residual concentrations of both toxic vapors in the different bins was probably due to the relative tightness of the bins, i.e., the amount of natural air circulation and resulting dilution effected.

Medical Study

CARBON tetrachloride has long been recognized as a hepatotoxin. More recently, it has been reported that CS_2 may also have toxic effects on the liver.[4,5]

A series of liver function tests was performed on six workers in September, at the close of the fumigation season, and repeated one month later, to determine if there had been any hepatic damage. These six workers included the four members of the state fumigation crew and two members of a county bin-site crew who had previously received high exposures to the fumigant vapors. Each man was also questioned about past illnesses, diet and alcohol intake.

Blood samples were collected in the field (Fig. 7), allowed to clot, placed in an ice-cooled insulated box, and delivered to the laboratory the same day. The following tests were performed: total blood protein; albumin; globulin; cholesterol and cholesterol esters; total, direct, and indirect bilirubin; cephalin flocculation; thymol turbidity; phospholipids; and serum transaminase.

Fig. 7.
Blood sample being taken in the field from member of a full-time fumigation crew.

Medical Findings

THE results of all laboratory tests fell within normal ranges, except the cholesterol which was above normal in four individuals and the cholesterol-cholesterol ester ratio which was decreased in one individual. It is unlikely that these are indicative of any extensive damage to the liver, since the other tests were normal; they may, however, be related to the CS_2 content of the fumigant.[6,7]

Recommendations

THE recommendations made to the Department of Agriculture included:

1. Fumigation should be performed only by well-trained and indoctrinated crews. Strict supervision should be exercised at all times. Seriousness of high exposures to the vapors of the fumigant should be continuously emphasized to the crew members.

2. A medical program should be instituted for all persons exposed to fumigant vapors. Regularly scheduled medical and laboratory examinations should be carried out:

(a) before the start of the fumigation season;

(b) if any unexplained illness occurs while at work;

(c) at the close of the season.

Medical and laboratory studies should be especially designed to detect renal, hepatic, and central nervous system injury.

3. All fumigation crew members should be provided with approved full-face gas-masks and organic vapor canisters. The mask should be put on and checked for leaks before fumigation starts, and should not be removed until the crew member leaves the area of high vapor concentration. If the odor of solvent is detected while wearing the mask, the crew member should leave the area immediately. The pump tenders need not use their respirators unless located downwind.

4. Especially designed equipment should be obtained to permit the gas-mask canister to be worn on the back of the fumigator, rather than on the chest. This will keep the canisters out of the heaviest vapor concentration, and should increase their useful life.

5. Full advantage should be taken of prevailing air movement in locating fumigation equipment, to reduce exposure of the pump operator and other crew members.

6. Fumigation should be discontinued when adverse weather conditions (i.e., no air movement) allow high vapor concentrations to build up in the entire area.

7. County bin-site crews should be provided with standard fumigation equipment including pump and spare parts, hose lines, and nozzle with cut-off valve, and given detailed instructions.

8. The grain storage supervisors should have full responsibility in their district for good fumigation practices including adherence to safety measures, maintenance of equipment, proper use and maintenance of gas-mask, and use of correct amount of fumigant. The supervisors should also have the authority to enforce safe fumigation practices.

9. Following fumigation, the bins should not be entered without a mask until a minimum of seven days have passed. It would be advisable to open the hatches or doors of the storage structures about half an hour before they are entered.

10. Workers should be completely clothed to prevent absorption of the toxic fumigant vapors through the skin. Special precautions should be taken to prevent skin contact with the liquid fumigant.

11. Efforts should be continued to develop or utilize a fumigant which is effective toward infestation control, but relatively nontoxic to humans.

Summary

A STUDY was made by the Occupational Health Field Headquarters during the period July to October, 1956, of the potential health hazards in the fumigation of shelled corn purchased and stored by the Commodity Credit Corporation, U.S. Department of Agriculture. Measurements of carbon tetrachloride (CCl_4) and carbon disulfide (CS_2), constituents of the fumigant, were made at the various operations of fumigation and subsequent corn inspection. Medical studies of liver function were carried out on six of the exposed workers.

Fumigant concentrations at the intake of the gas-mask canisters worn by the fumigators were often found to exceed the canister's safe limit. The fumigation crew members, when not wearing masks, were exposed to excessive amounts of the toxic vapors intermittently. After fumigation, the relative tightness of the storage bins influenced the concentration of residual vapors. The concentration of solvent vapors in some bins fell within threshold limit values within one day, while others maintained greater than threshold limit concentrations after seven days. Liver function tests in six men showed no evidence of acute or chronic damage.

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A Radiological Health Program

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PRIOR to the advent of the atomic era, there was little emphasis on radiation protection from the public health standpoint. Relatively small numbers of persons were exposed and radiation protection was generally considered to be primarily the responsibility of the individual. Although the use of x-rays was becoming more widespread, the potential dangers of radiation exposure was not generally recognized.

Recognition of the Radiation Hazard

THE RESEARCH studies conducted during and since World War II on the biological effects of radiation exposure have pointed out the potential dangers from excessive exposure to ionizing radiation to the public and to persons working with this form of energy. As a result, state agencies responsible for public and occupational health now recognize that the control of radiation exposure is an extension of their long-standing responsibilities to control any life or health hazard that exists in the public or occupational environment.

The fear that atomic research activities, such as those conducted at Brookhaven and Knolls Atomic Power Laboratory, would create a serious hazard to the environment prompted several New York State agencies to enter the field of radiation protection. It was not until 1952, however, that both the New York State Health and Labor Departments began extensive studies of the potential public and occupational radiation hazards in New York State and the State's responsibilities in this field.

Regulation of Radiation Exposure

ONE of the first steps taken by the Departments of Health and Labor was the development of a regulation to control the operation of shoe-fitting fluoroscopes. This regulation was promulgated as part of the State Sanitary Code and became effective July 1, 1953. About the same time, both Departments appointed radiological health advisory committees to study the entire problem and make recommendations for its control. Although these two committees worked more or less independently, each arrived at essentially the same conclusion; namely, that radiation control programs should be conducted by the respective departments and that regulations in the form of codes should be promulgated. As a result, Chapter XVI of the State Sanitary Code, and Industrial Code Rule #38 were adopted in 1955. The objective of both codes was to control radiation hazards effectively without hampering technicological development in the use of ionizing radiation and nuclear energy.

Jurisdictional Areas

IN NEW YORK STATE, responsibility for health protection is divided between two agencies. The Labor Department has responsibility for occupational health and the Health Department for public health. Since it is often difficult to define the jurisdictional areas of these two agencies in these two broad fields, plans for the proposed activities of each Department in the radiological health program had to be closely coordinated to avoid overlapping of jurisdiction by the controlling agencies and confusion among those subject to or under control. This was successfully accomplished by the establishment of close liaison between the departments, first through the Interdepartmental Health

Council and later through the Council on the Use of Nuclear Materials.

A general agreement was reached between the Labor and Health Departments whereby the Health Department would concern itself with installations where ionizing radiation is purposely applied to human beings as in the diagnostic and therapeutic use of x-ray and radioisotopes, and with installations, such as those that discharge radioactive wastes, where the use of such radiation might be hazardous to the public. On the other hand, the Labor Department would concern itself with those installations where only occupational exposures occur.

One of the practical results of this definition of jurisdictional areas was the disclosure that potential radiation hazards at some installations were not covered by present laws or regulations. For instance, public utilities are routinely supervised by the Public Service Commission. Generally, neither the Labor nor Health Departments has jurisdiction over industrial hygiene within a utility. On the other hand, there is nothing in the Public Service Commission rules that would give them jurisdiction over radiation hazards in any power reactor. In the case of nuclear power reactors, the Health Department, under its broad public health prerogatives, does have power to control radioactive wastes discharged to the environment.

Training of Staff

WITHIN each department, the necessity for carrying on a radiological health program and enforcing the respective codes has forced decisions regarding the recruitment and training of personnel as well as the use of certain professional skills. The skills needed in conducting field investigations and in administering the programs were not available in either department. Since personnel with radiological health training were in critical demand, it became necessary for the departments to train their own personnel to conduct activities in this field. The magnitude of this task can be appreciated when it is stated that the State Health Department's activities are carried on through 45 field offices, each responsible for a segment of the State and each fully manned with professional personnel consisting of physicians, nurses, sanitary engineers and sanitarians. The Labor Department's activities are carried out through a smaller number of field offices with larger staffs.

The concept that public health personnel who are experienced in dealing with environmental hazards can acquaint themselves adequately with the instrumentation, survey methods and control techniques of radiation, has been shown to be administratively and technically feasible. Likewise, industrial hygienists who are experienced in dealing with other hazards in industry can acquaint themselves adequately with the radiation problem and with methods for its control.

Training programs for the Health Department staff were initiated early in 1955 with the cooperation of the radiological health training section of the Sanitary Engineering Center in Cincinnati. This staff conducted a number of basic radiological health courses in New York State. To carry the training program farther, the personnel of the Atomic Energy Project at Rochester University conducted courses for state personnel in survey methods and instrumentation. It is planned that radiological health training will become a part of the routine in-service-training program now being carried on for personnel in the state departments.

Registration of Radiation Installations

THE PROVISION in Chapter XVI of the State Sanitary Code and in Industrial Code #38 that all radiation installations be registered is identifying effectively the uses and users of radiation in New York State. Knowledge of where and how much radiation is used is the basis for effective control. In the first year, well over 300 industrial installations were registered with the Labor Department and well over 2,000 installations were registered with the Health Department. While there was some gen-

eral knowledge as to the sources and types of radiation prior to the effective date of the codes, the precise number of units, variety and amount of radiation were not accurately recorded until registration was required. Knowledge of the number and location and variety of registered users provides a practical basis for planning future programs and regulations.

In New York State, both of the regulatory agencies require registration rather than licensing. Licensing would entail an unproductive administrative chore, whereas registration requires only a small administrative force and yields the same information as the licensing procedure. In all cases, responsibility for registration is placed on the operator of the installation rather than on the suppliers or manufacturers of radiation producing equipment and radioactive materials. The assistance of such suppliers and manufacturers is most helpful. In most cases, they have given complete and continued support. Letters were sent to most firms and individuals notifying them of the existence of the requirement for registration and a number of follow up letters have been sent out in an effort to obtain complete registration. A great amount of follow up work has been necessary, however, because not all operators have been conscientious in registering their installations.

Cooperation of Other Agencies

THE COOPERATION of non-governmental agencies, such as the state dental, medical, veterinary medicine and radiological societies, was solicited and obtained. Representatives of these agencies served on advisory committees to study the problem and have supported the regulation of radiation exposure. A few of the societies and organizations have appointed special committees on radiological health to assist in the state program; others are handling these activities through existing health committees. The support of these organizations has paid dividends. The organizations became acquainted with the over-all problem and the objectives of the program, and, therefore, could solicit the assistance of their members in supporting the program. It is significant that no objection has been raised by any of these organizations to the adoption of regulations and the administration of a program to reduce radiation hazards.

While the enactment of codes has been a motivating factor in the provision of many safeguards to reduce radiation hazards, the educational program carried on in cooperation with various committees representing the professional societies, has also been quite productive. Formal conferences for radiation users sponsored by the Labor Department and conducted at Universities have played an important part in bringing about an increasing awareness of the objectives sought. Insofar as practical, education rather than policing to achieve compliance with regulations is being utilized. Performance rather than specificity is being stressed. Users of radiation now realize that all radiation exposures must be kept as low as possible since each exposure is a burden that the race as a whole must carry.

Administrative Problems

THE ADOPTION of codes has pointed up some problems which were recognized even before the codes were promulgated. While the solution of these problems may not come for years, a practical compromise or solution is being accelerated by the fact that codes must be enforced. Major questions still to be answered are:

1. *What constitutes an adequate survey or appraisal of a radiation hazard?* Both existing codes require that surveys be made to evaluate radiation hazards. Some hazards are relatively easy to evaluate while others are quite difficult. Committees have been appointed to work on this problem.

2. *Who is qualified to carry out a survey?* At present, there is no legal body to pass upon the qualifications of health physicists or other persons who may be competent. After many conferences with educators, physicists and others, it is evident that some certifying or qualifying procedure

must be developed within the next few years.

Until recently, no authority was designated in any law to establish minimum qualifications of this type. However, during the 1957 session of the Legislature, the Public Health Law was amended to allow the New York State Public Health Council to establish such minimum requirements and to certify qualifications of radiation survey officers. Within the next year, the Health Department proposes to recommend minimum standards to the Public Health Council.

3. *What types of records should be maintained?* From a practical standpoint, little progress has been made in developing standard methods of recording radiation exposure. The maintenance of meaningful, cumulative medical data of an individual's exposure to internal and external sources of radiation is a particularly difficult one. Such data become even more important in light of the recent recommendations of the National Committee on Radiation Protection relating to the cumulative dose of radiation workers and the environmental exposure of the public.

4. *How can the effectiveness of radiological health programs be evaluated?* While a great deal is known about the biological effects of radiation, it is difficult to establish the cause and effect relationship particularly since damage to the individual or the public may not appear until long after injury is sustained. Then too, radiation injury may manifest itself in the form of diseases or injuries which are similar or identical to diseases or injuries sustained from other agents or which are presently considered to be diseases associated with old age.

The frequency or severity of radiation accidents might be one criterion that could be used to evaluate a program of this type but this, even at best, is only a partial solution. There are no accurate or complete records with which to make a comparison. Both New York State codes require the reporting of accidents and over-exposure, but it is quite probable that these occur with greater frequency than has been indicated by the reporting during the past one and one-half years that the codes have been in effect. In all, only two accidents and no over-exposure have been reported.

Research and Special Studies

A NUMBER of special studies have been made or are being conducted by the departments in New York State. These include: hazards associated with shoe-fitting fluoroscopes; hazards associated with the veterinary use of x-rays; congenital malformation rates and their relation to normal radiation background; measurements of background radiation levels in public water supplies and major streams and daily fallout determinations. In order to carry out these special investigations and the routine program, a large number of survey and laboratory instruments had to be purchased and laboratory space provided. Laboratory space posed a particular problem since the facilities of the Health Department laboratories were already critically over-loaded. Plans are now being made for the construction of additional permanent facilities. Meanwhile, temporary facilities are being constructed to house the radiochemistry and calibration laboratories.

Summary

THE ADOPTION of codes in New York State have provided a tool to expedite the reduction of radiation hazards. They serve as well for compiling factual data on which plans for protective programs can be based. They have pointed out the problems still to be faced. The control of radiation hazards has not imposed any hardship on industry, the medical profession, or other users of radiation. The practicability of adopting codes which set up standards for performance and only minor specifications for the control of radiation has been validated by actual experience in New York State. A great deal remains to be done but the first steps which have been taken have been intelligent, non-restrictive and practical.

EVALUATION OF THE

Carbon Monoxide Hazard from Indoor Use of Propane-Fueled Fork Lift Trucks

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IN RECENT years, the industrial use of all types of fork lift trucks has greatly increased. Since these trucks are often driven into boxcars, trailers, and confined warehouse areas where ventilation, if any, is poor, a potential carbon monoxide hazard results. For example, we have measured carbon monoxide concentrations as high as 400 PPM when a lift truck was used to stack pallets inside a warehouse and have found 1000 PPM during a boxcar unloading. In each of these cases, the trucks used were fueled by gasoline.

Generation of Carbon Monoxide by Internal Combustion Motors

EXCESSIVE generation of carbon monoxide gas is one of the inherent weaknesses of gasoline as an engine fuel. Being a liquid, gasoline must be vaporized before it will burn. Since it is a mixture of chemical compounds rather than a single compound, it has an extended boiling range. Usually it begins to boil at about 100° F and continues on up to 350° F. If an engine were designed so that the fuel could be preheated enough to vaporize the heavy ends of gasoline before it was introduced to the combustion chamber, the light ends would be vaporized and expanded to such an extent that only a small amount of fuel would fit into the cylinder and a weak explosion would occur. If the gasoline is not heated enough to vaporize the heavy ends, they tend to settle out as the fuel-air mixture is carried through the intake manifold. This results in a rich mixture especially at idling speeds when the flow rate through the manifold is relatively low. The term, rich mixture, indicates that the fuel-air mixture is relatively rich in gasoline and lean in air. When this mixture burns, the air is all used up but the fuel is not competely burned. The exhaust gases, therefore, contain appreciable amounts of carbon monoxide and of aldehydes.

Methods of Reducing Carbon Monoxide Hazard

CARBON monoxide concentrations within industrial buildings can be reduced by using electric fork lift trucks, general ventilation, local exhaust, catalytic units, or by substituting propane for gasoline.

Electric fork lift trucks. Electric trucks are 100% effective in eliminating the carbon monoxide problem and are preferred by insurance companies to either gasoline or propane fueled vehicles. A disadvantage has been their higher initial cost and decreased power at low speeds.

General ventilation. To reduce carbon monoxide concentrations by dilution with fresh air is often impractical; for example, carbon monoxide is a problem in cold storage warehouses where gasoline-fueled fork lift trucks are used. To eliminate the problem by general ventilation would be very costly since it would be necessary to exhaust air which it had cost money to cool and bring in warm fresh air which would have to be cooled down to the temperature of the warehouse. Other typical working areas such as the interior of boxcars and trailers are also difficult to ventilate.

Local exhaust. There are some locations where local exhaust is applicable. It can be used in garages and vehicle maintenance shops where the cars and trucks must

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occasionally have their motors running while being tuned. Since the vehicles are stationary, local ventilation by means of flexible ducts or built-in floor ducts can be very effective. It would be difficult to imagine any type of local exhaust which could be effectively applied to a moving fork lift truck.

Catalytic units. In a catalytic exhaust unit, the carbon monoxide laden exhaust stream is mixed with fresh air and passed over a heated catalyst where the gas is burned to carbon dioxide. We have made no special study of these units and do not feel qualified to evaluate their performance.

Propane gas. While the use of propane as a fuel for fork lift truck engines does not completely eliminate the carbon monoxide hazard, it does have several advantages over gasoline. One leading fork lift truck manufacturer now devotes 80% of his output to propane powered units as compared to 20% a year ago.

Liquified petroleum gas is commonly abbreviated as L.P.G. and is a mixture of gaseous petroleum compounds. The commercial product is sold under the name propane, and the composition usually runs about 95% propane and 5% butane, with trace quantities of ethane, ethylene, propylene, butylene, and isopentane. Propane is a gas at ordinary temperatures and pressures. It can mix completely and uniformly with the air in the carburetor and burn almost completely in the engine to carbon dioxide and water. Propane has an octane rating of 125. Therefore, it needs no tetraethyl lead and produces no lead bromide* in the exhaust gases. Although propane has only 80% of the heat equivalent of gasoline, it is quite common to get the same mileage from propane as from gasoline because propane is burned more efficiently in the engine.

As far as the carbon monoxide hazard is concerned, propane-fueled trucks offer a compromise between gasoline-fueled and electric-powered trucks. A well-tuned propane-burning engine should discharge less than 0.1% of carbon monoxide at the exhaust outlet as compared with 1.5% in the exhaust gas from a well-tuned gasoline-fueled engine and 6% to 7% from an engine not properly tuned (a more common case).

*To avoid lead oxide depositing on the cylinder walls a compound such as ethylene dibromide may be added to gasoline.

Comparison of Carbon Monoxide Levels from Gasoline and Propane Units

TO OBTAIN a fair comparison of carbon monoxide concentrations prevalent during the use of gasoline and propane-fueled trucks, a field test was conducted. Two comparable model fork trucks (Towmotor Model LT 35, 2000 lbs) were used, similar in all respects except that one burned gasoline and the other propane. The gasoline-fueled engine had had new spark plugs installed and was carefully tuned prior to the test. The propane unit had not been tuned since installation of the conversion unit about a year prior to the test but was considered in good working order.

The work situation was the unloading of two exactly similar trailers each containing baled cellulose acetate and having a capacity of about 1800 cubic feet. The trailers were unloaded on the same day at adjacent bays in a large warehouse.

Nose level carbon monoxide concentrations were measured at five-minute intervals throughout the unloading period. Fig. 1 shows graphically the results of this test. During the use of the propane-fueled vehicle, carbon monoxide concentrations never exceeded 16 PPM (with an average of 6 PPM) whereas carbon monoxide issuing from the gasoline-fueled engine almost im-

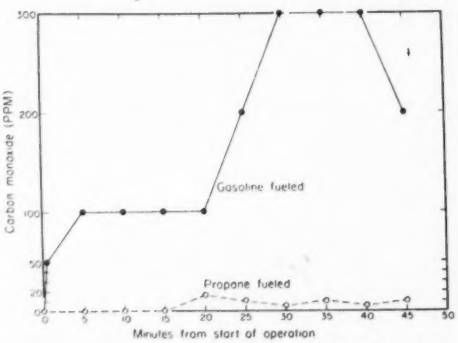

Fig. 1.
A comparison of carbon monoxide concentrations accompanying the use of gasoline and propane fueled fork lift trucks during identical work situations.

mediately reached a concentration of 50 PPM and remained over a prolonged period at 300 PPM with the average level being 162 PPM.

Another hazardous condition developed during the unloading of boxcars containing bulk sulfur. This was an extremely demanding task and certainly placed maximum stress on both machine and operator. A gasoline-fueled front-scoop truck was used. When this vehicle worked in the dead ends of the boxcars, carbon monoxide concentrations reached 1000 PPM and averaged 360 PPM. A propane conversion unit was installed but the initial installation failed when the converter froze up. This resulted from poor circulation of hot water from the radiator through the converter. Installing a water pump solved the problem and has permitted the continued use of this vehicle for sulfur unloading. Since this conversion, the carbon monoxide concentrations within the boxcars have never exceeded 150 PPM and will normally average about 75 PPM.

Other plant tests have confirmed the ability of a well-designed and properly installed conversion unit to reduce the carbon monoxide hazard.

An Example of a Propane Conversion Unit

TRUCKS now fueled by gasoline can be readily converted to propane: this offers a way to decrease the hazard from the many gasoline-fueled fork lift trucks which are now in use and could not be economically replaced. In the case of small engines, such as used in fork lift trucks, the gas tank and fuel lines are removed and are replaced by a propane cylinder and a pressure reducer. The propane is fed into the regular gasoline carburetor at the venturi by drilling a hole in the carburetor and brazing in the fuel line. Fig. 2 is a schematic drawing of a system approved by insurance companies. The features which are considered to be important with regard to safety are included in this drawing and should be carefully noted.

The propane cylinder (1), which is easily removed by the quick disconnect coupling (2), has a manual shutoff valve (3) and a built-in excess flow valve (4). If the fuel line (5) is broken, this valve automatically closes and prevents the contents

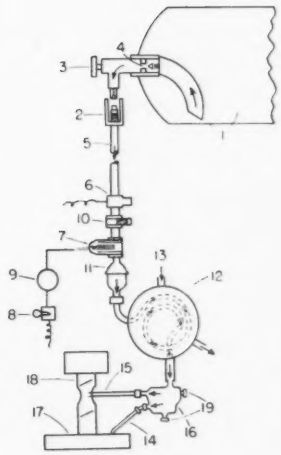

Fig. 2.
A propane fuel conversion system approved by insurance carriers for installation on fork lift trucks.

of the cylinder from discharging to the atmosphere. The quick-disconnect valve has spring-loaded shutoffs which close as soon as the valve is disconnected so that no fuel can leak out of the tank or the line.

Flexible hose is used to bring the propane to the engine because it can withstand the vibration and flexing better than any other kind of fuel line.

The pressure switch (6) is connected to a red light on the dashboard and warns the operator when the liquid propane is used up and only vapor remains in the system. This gives him a few minutes to get back to the fueling station where he can exchange cylinders without carrying them by hand.

The solenoid valve (7) shuts off the fuel supply until the ignition switch (8) is turned on. The electrical circuit for this valve is connected in series with an oil pressure switch (9). If the engine should be left running while unattended and should stall, the oil pressure would drop, thus closing the solenoid valve even though the ignition is still turned on.

A pressure relief valve (10) in the line between the manual shutoff and the solenoid relieves the pressure which would build up if these two valves were closed and the vehicle parked in a warm place.

The fuel filter (11) removes any particles of scale that might damage the valves of the converter.

The converter (12) contains a two-stage pressure reducer which changes the propane from a liquid under 150 psi pressure to a gas at atmospheric pressure. The heat required for this expansion and evaporation is supplied by water (13) from the radiator circulated through a coil in the converter. Most engines have a water pump that furnishes a driving force to circulate the water. In a few smaller engines that do not have a water pump but depend on the difference in specific gravity of hot and cold water to furnish the driving force, it is essential to locate the converter midway between the top and bottom of the radiator and keep the water lines as short and straight as possible.

Propane is drawn from the converter through an adjusting block and into the engine by the vacuum caused by the pistons going down in the cylinders. In the absence of this vacuum, no vapor is released from the second stage of the converter. An electric primer button, located on the dash, actuates the valve leading from the second stage to release vapors when the engine is started. There are two lines going from the adjusting block to the engine. One (14) is used primarily for idling. It is connected directly to the intake manifold (17). The other line (15) is spudded into the carburetor (18) so that the outlet is in the center of the throat at the venturi. It is important to have these two separate lines with a needle valve on each in order to achieve maximal combustion of the fuel under all operating conditions. If the fuel system has only one line from the converter to the engine, it cannot be adjusted to give a perfect combustion mixture under *both* idling and full power conditions. If the engine idles properly, it will lack pep under full load. Usually such engines are adjusted to give good performance at full load and, consequently, the *idling mixture is too rich*. As a result, the fuel does not burn completely when the engine is idling. The odorant which has been added to the propane can be detected in the exhaust gases and helps to indicate when the concentration of carbon monoxide is too high*.

Safety Considerations for Propane-Fueled Motors

THE TANKS, valves, flexible hoses and other devices employed in the propane fuel system are ruggedly built. The pressure relief valves, excess flow valves, solenoid shutoff, oil pressure switch, and the pressure controlled valves in the converter have been carefully designed and give a real measure of protection.

Under some circumstances, high carbon monoxide levels can develop even when propane is used. This was illustrated in a recent report in the *AMA Archives of Industrial Health* which described an incident involving three propane-fueled trucks operated in a cold storage plant. One operator collapsed while working in the area. Carbon monoxide concentrations were found to be 400 PPM on the day following the exposure.[1] Apparently this accident occurred in a very poorly ventilated area (temperatures were kept at -10° F) and resulted from a day-to-day buildup of carbon monoxide. Oxygen deficiency should also be considered as a possibility. The incident emhasizes that exhaust gases from propane-fueled engines are not entirely free of carbon monoxide and trucks burning propane cannot be safely used for prolonged periods in confined, unventilated areas.

Probably the one remaining possibility of danger is the fact that a slow leak from an unattended machine over a period of time can cause dangerous amounts of an explosive gas to accumulate. Propane is heavier than air. Explosive mixtures may accumulate in low spots needing only a spark to be ignited. A recent explosion in Illinois was caused by propane drifting 175 feet down a slope out-of-doors into a cellar window where it was ignited by a pilot light.[2] The leak was in a hose which had a valve at each end. The operator, having neglected to shut off the valve leading to the hose, had ignored one of the safety devices that was installed on the truck and had allowed a slow leak to occur over a long period of time.

*Odorant ". . . shall be . . . 1.0 pounds of ethyl mercaptan, 1.0 pounds of thiophane or 1.4 pounds of amyl mercaptan per 10,000 gallons of LP Gas." National Board of Fire Underwriters, *Standards for the Storage and Handling of Liquified Petroleum Gases*, NBFU No. 58 (as recommended by the National Fire Protection Association), June, 1956, page 5.

Precautions to be Observed

STANDARDS Bulletin No. 58 of the National Board of Fire Underwriters (as recommended by the National Fire Protection Association) describes precautions to be observed when storing and handling Liquified Petroleum Gases. These procedures are aimed at minimizing the very real explosion hazard which can be associated with the mishandling of propane.

Factory Mutual Bulletin No. 7-46 warns that the use of LP-Gas trucks should be limited to ordinary hazard occupancies. This same bulletin advises that when propane-equipped fork lift trucks are to be left unattended overnight or if the cylinders are changed indoors, the manual shutoff valve on the supply cylinder should be closed, the motor should be kept running until the fuel is bled out of the lines and then the ignition key turned off. The cylinder should then be removed from the truck and put in a safe storage area such as out-of-doors or in a room with mechanical ventilation from the floor level and isolated from the rest of the building by a firewall. The outdoor storage should not be near a cellar window.

Summary

CONSIDERING the use of fork lift trucks inside industrial buildings with regard to health hazards leads to the following conclusions:

1. Electric trucks are to be preferred whenever their use is practical.

2. In our experience, a well-adjusted propane-fueled truck can be used for many operations where trucks fueled by gasoline have proved hazardous.

3. Fork lift trucks now fueled by gasoline can be readily converted to the use of propane. Our experience indicates that when done properly this is a practical and safe procedure. Satisfactory conversion kits are now on the market.

4. Any internal combustion engine is capable of generating dangerous concentrations of carbon monoxide and their use in poorly ventilated areas should be carefully considered.

References

1. BLOOMFIELD, BERNARD D.: Lift Trucks Raise Carbon Monoxide Level. *AMA Archives of Industrial Health*, 15:171, 1957.

2. National Fire Protection Association: Delayed Evacuation. *Fire News*, November - December, 1956, page 9.

AAAS Meeting

THE ANNUAL meeting of the American Association for the Advancement of Science will be held December 26-31, 1957, in Indianapolis. The AMERICAN INDUSTRIAL HYGIENE ASSOCIATION is cosponsoring a symposium of several sessions under Section M—Engineering. The general title is "Measuring Man's Environment." Papers concerning the physical effects on man of light, temperature, sound and air will be included. Two of the speakers are DR. CHARLES WILLIAMS, Boston, President of the American Industrial Hygiene Association and CHARLES YAFFE, Cincinnati, member of AIHA Board of Directors.

A Method of Presentation of Data

HEALTH HAZARDS AND PRECAUTIONS FOR SAFE HANDLING OF MATERIALS

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Biochemical Research Department
The Dow Chemical Company, Midland, Michigan

FOR SOME TIME, it has been recognized by Industrial Hygienists and Toxicologists that there is a need for a clearer expression of the character and degree of hazard associated with a particular chemical in a particular type of industrial operation. A project with this objective, regarding materials pertinent to its processing and development, has been in operation within The Dow Chemical Company for approximately two years. Usefulness for the distributed information has been demonstrated sufficiently to warrant its presentation at this time.

Steps Taken

IN BRIEF, an endeavor has been made to place specific information of a practical nature in the hands of all supervisory personnel concerned with safe handling precautions necessary for the protection of workmen. The accomplishment of this aim has been divided into three phases: (1) translation of toxicological data obtained on animals into a description of probable effect upon human beings; (2) definition of the nature and extent of health hazard presented by a given material in various types of industrial exposures ranging from hand operations to operations by remote control; and (3) description of precautionary measures and protective devices necessary to reduce the hazard encountered in such specific situations to an acceptable level.

The manner in which such conclusions are reached may be described best in an explanation of the form in which the data are being distributed. It was believed that a single sheet, front and back, could be used to describe each substance (see sample form on pages 362 and 363).

Presented at the Eighteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, April 24, 1957, at St. Louis.

The "Properties"

Physical and Chemical

PROPER identification of a material requires that certain appropriate physical and chemical attributes be described, including, for example, chemical name and synonyms, molecular formula, structure and such characteristics as boiling point, flash point and physical state. Corrosiveness is intended to refer to effect upon common metals. Chemical reactivity is noted for those materials dangerously so; whereas, stability refers to the effects of heat, light and pH changes.

Toxic Classification

THE CLASSIFICATION of toxic properties usually is based upon the results of observations in experimental animals. Yet, if the presentation is to be useful to industrial supervisory personnel, it must be given in terms of probable effects upon human subjects. The ease and accuracy of such predictions are influenced by a number of factors other than the animal data, although laboratory methodology with a background of proven applicability to the evaluation of human responses is of prime importance in this regard. In the final analysis, the experienced toxicologist must exercise his own best judgment for interpretation of probable effects upon human subjects. Having done this, the next problem is one of presenting his interpretation in words understood by the layman.

The classification of toxic properties is divided by "type of contact" with each cate-

gory further broken down into distinct groupings according to the potential severity of effects. A detailed account of the testing procedures employed by the Dow Toxicology Laboratory is not appropriate at this time. However, it is believed that some reference to these procedures is necessary in order to illustrate the statements of toxic properties. Further, it should be emphasized that the groupings under each type of contact (eye, skin, inhalation, ingestion) have been made broad enough on a practical basis and yet close enough to minimize the number of problems presented by "borderline" situations.

Eye Contact

IN THE EYE irritation tests, for example, six "grades" of response are used to characterize the effects observed when materials are placed in the rabbit eye. For the Data Sheet, only three classes were believed needed for liquids and solids. A fourth is included for describing serious effects from materials in the vapor state.

Skin Contact

THE OBSERVATIONS resulting from single and repeated application of materials to the rabbit skin also in the laboratory are graded at six different levels. For the purpose of evaluating probable human response, however, four classes have proven satisfactory in the Data Sheet. In addition to the evaluation of such factors as duration of contact and frequency and type of skin response, systemic effects resulting from absorption through the skin are considered.

Thus, a material may be classified in the second category because "repeated prolonged contact may cause appreciable irritation" whereas, another material may go into the higher category (No. 3) only because of the possibility of "systemic injury, even death" from single prolonged or frequently repeated short contacts. The fourth category is reserved for those materials which rapidly cause severe burns or serious systemic injury (within seconds or minutes) following initial contact.

Inhalation

SPECIFIC data are seldom available concerning effects of exposure to the dust or mist of materials. The problem is sufficient, however, to warrant an estimate. There are four categories listed in this section. Irritation of the respiratory passages is an important consideration. The evaluation of possible systemic injury is accomplished through calculations based upon the degree of acute and repeated oral toxicity.

To classify the toxic properties of a chemical vapor, five categories have been used. In case the only available information is the result of the exposure of animals to "saturated" atmospheres, a system has been devised to accomplish such an interpretation. However, data which include the response of animals to known vapor concentrations of the material are preferred. This classification is presented in Table I. It has proven

TABLE I.
CLASSIFICATION OF TOXIC PROPERTIES FOR INHALATION OF VAPOR-ANIMALS

Class	Concentration Tolerated Repeatedly PPM	Single Exposures in PPM Having Minimal[1] Effects >0.5 hour	Single Exposures in PPM Having Minimal[1] Effects <0.5 hour	Single Exposures in PPM Having Serious[2] Effects >0.5 hour	Single Exposures in PPM Having Serious[2] Effects <0.5 hour
I	>1,000	>1,000–10,000	>100,000	>100,000	>100,000
II	>50–1,000	>300–1,000	>1,000–100,000	>1,000–100,000	>10,000–100,000
III	>10-50	>50-300	>300–1,000	>300–1,000	>1,000–10,000
IV	>1-10	>10-50	>50-300	>50-300	>300–1,000
V	1 or less	10 or less	50 or less	50 or less	300 or less

[1]Minimal: May be very slight anesthesia (drowsiness) and/or some slight, transient irritation and pain to the eyes and/or some slight systemic effects not believed to be lasting or of a serious nature.

[2]Serious: Appreciable anesthesia and/or systemic injury, including death, and/or serious irritation or pain to eyes or respiratory passages.

a useful guide in translating such data into terms of probable effects on human subjects. The intensity of exposure tolerated repeatedly (seven to eight hours daily; five days a week) is an important consideration in the over-all vapor toxicity evaluation.

Critical points useful in the classification of materials on the basis of parts per million of the vapor in the atmospheres to be breathed appear to be the effects at "less than" or "greater than" 0.5 hour, and whether the effects are minimal or serious (See footnote of Table I).

Ingestion

THIS TYPE of contact usually is not a serious problem in industrial handling of materials. It is important, however, to recognize those materials which may be classed as "highly toxic" either by acute or chronic

BIOCHEMICAL RESEARCH DEPARTMENT
THE DOW CHEMICAL COMPANY
MIDLAND MICHIGAN
DATA SHEET OF PROPERTIES, HEALTH HAZARDS, AND PRECAUTIONS FOR SAFE HANDLING OF MATERIALS

MOLECULAR FORMULA		CHEMICAL NAME
MOLECULAR WEIGHT	INDUSTRIAL HYGIENE STANDARD	SYNONYMS
STRUCTURAL FORMULA - OR COMPOSITION		

PHYSICAL AND CHEMICAL PROPERTIES

BOILING POINT °C mmHg.	EXPLOSIVE LIMITS (% BY VOL. IN AIR)	FLASH POINT °F.	IGNITION TEMP. °C.	MELTING POINT °C.	VAPOR PRESSURE mm Hg 25°C
CORROSIVENESS (To Common Metals)				PHYSICAL STATE	COLOR
CHEMICAL REACTIVITY				ODOR (Include Concentration in Air)	
STABILITY (To pH Change, Heat, Light)					

TOXIC PROPERTIES

TYPE OF CONTACT		CLASSIFICATION OF TOXIC PROPERTIES	
EYE		☐ May cause no response or no more than very slight to slight transitory pain and/or irritation of the eyelids.	☐ May cause some permanent loss of vision (this includes damage to cornea or internal injury which is incompletely healed in one week.)
		☐ May cause sufficient injury to the eye to result in loss of time from work. (This includes damage to the cornea which heals or nearly heals in a week and/or considerable conjunctival irritation with edema.)	☐ Vapor exposure may cause severe pain, lacrymation or serious injury to the eyes.
SKIN		☐ Single prolonged exposure (hours) causes no effect. Several repeated prolonged exposures may or may not cause the development of some slight irritation.	☐ Single short exposure (minutes) may cause considerable irritation and/or single prolonged or frequently repeated short exposures cause a burn and/or may cause systemic injury, even death.
		☐ Single prolonged exposure may cause some reddening of the skin. Repeated prolonged contacts may cause appreciable irritation, possibly a mild burn and/or may cause appreciable systemic injury due to absorption.	☐ An exposure rapidly causes severe burns and/or serious systemic injury, even death.
INHALATION	DUST OR MIST	☐ No systemic injury expected. No irritation to nose and throat in dusty or misty atmospheres.	☐ Dusty or misty atmosphere painful to nose and throat (intolerable to most people) and/or exposure may cause serious systemic injury.
		☐ Throat and nose irritation in a dusty or misty atmosphere is painful but not intolerable and/or prolonged or repeated exposures may cause systemic injury.	☐ Short exposure (minutes) may cause death or serious systemic injury.
	VAPOR	☐ Exposures do not cause any effects other than some very slight irritation or pain to the eyes or respiratory passages at the most.	☐ Exposures may cause extreme drowsiness, and/or serious systemic injury, and/or may cause intolerable irritation to the respiratory passages.
		☐ Single exposures exceeding 1/2 hour, or frequently repeated exposures of shorter duration, may cause slight anesthesia and/or slight systemic injury, and/or cause appreciable, but not intolerable, irritation of respiratory passages.	☐ Short exposures may cause unconsciousness, and/or serious systemic injury, including death.
		☐ Even very short exposure will cause serious systemic injury or death.	
INGESTION		☐ Amounts which may be swallowed incidental to industrial handling will not cause injury. However, if substantial quantities should be swallowed, more or less serious effects may occur.	☐ Amounts which may be swallowed incidental to industrial handling and use may cause serious injury.

COMMENTS

ingestion, so as to identify those materials which may present a problem should the hands, face, food, or tobacco become contaminated. As a guide in classifying most substances, an acute survival dosage for experimental animals of 0.1 g/kg or a "safe" dietary level of 100 ppm have been used as a rough approximation for dividing those materials presenting an appreciable hazard from those which do not.

Degrees of Exposure Related to Types of Operation

THE TYPES of industrial jobs have arbitrarily been divided into four categories based upon the likelihood of contact believed to exist in the methods of operation listed in the examples. In brief, the conditions are visualized somewhat as follows:

DEGREES OF EXPOSURE RELATED TO TYPES OF OPERATION		PRECAUTIONS *(SEE CODE BELOW)*				
		EYES	SKIN**	INHALATION*		INGESTION
				DUST OR MIST	VAPOR	
I NO CONTACT	Characterized by remote operation with equipment isolated from the work area. The persons entering isolated areas will require the personal protection outlined for IV below.					
II MINOR CONTACT	Characterized by closed systems with equipment vented outside the work area; instrument control; mechanical handling of materials in bulk. Examples are: continuous reactors, stills and filters; enclosed conveyors; ventilated packaging.					
III OCCASIONAL DAILY CONTACTS	Characterized by manual handling of materials in packages such as bags, drums and fiberpaks. Ventilation may be provided for specific jobs. Many batch operations fall into this category.					
IV GROSS CONTACT LIKELY	Characterized by hand operation. Examples are: Emergency repairs, cleaning equipment, cleaning filters, taking care of spills, packaging volatile or dusty materials without ventilation, wheeling and tray drying.					

EYE CONTACT

- **A** No eye protection needed.
- **B** Use safety glasses without side shields.
- **C** Use safety glasses with side shields.
- **D** Use chemical workers goggles.
- **E** Use gas tight goggles or a full face gas mask.

SKIN CONTACT**

- **A** A bath and clean clothes once per week along with the usual washing at mealtimes should be adequate precautions.
- **B** Grossly contaminated clothing and shoes must be removed not later than the end of the work period and must be thoroughly cleaned before re-use.
- **C** Require shower at the end of the work period and clean clothing from the skin out at the start of each work day.
- **D** Clothing should be changed and skin washed promptly upon any detectable contact. Each use will require special consideration to determine suitable protective devices and standards of personal cleanliness.
- **E** Impervious clothing such as rubber boots, rubber aprons, and rubber gloves will be required. Specific items will be dictated as required by circumstance.

INHALATION

DUST OR MIST

- **A** No respiratory protection.
- **B** No protection required for exposure of thirty min. duration or less to obviously dusty atmospheres. Exposures of longer duration will require the use of a dust respirator bearing the approval of the U. S. Bureau of Mines for the use with toxic dusts.
- **D** Any exposure to obviously dusty atmospheres will require a dust respirator bearing the approval of the U. S. Bureau of Mines for use with toxic dusts.
- **E** Any exposure to dusty atmospheres will require the use of an airline respirator, blower mask, or Chemox mask.

VAPOR

- **A** No precautions necessary.
- **B** No precautions necessary for single exposures of less than 1/2 hour. Longer single exposures, or frequently repeated exposures will require a gas mask or respirator equipped with appropriate canister.
- **C** No precautions necessary for single exposures of no more than ten minutes. Longer exposures either single or repeated, will require gas mask or respirator equipped with appropriate canister.
- **D** Gas mask with appropriate canister required at all times.
- **E** Evacuate area at once and enter only with airline respirator, blower mask or Chemox mask.

INGESTION

- **A** No unusual procedures required.
- **E** Food and tobacco should not be present in the work area. Hands and face should be washed before smoking and eating.

COMMENTS

**GOOD PRACTICE REQUIRES THAT GROSS AMOUNTS OF ANY CHEMICAL BE REMOVED FROM THE SKIN AS SOON AS IS PRACTICAL

*SUITABLE GAS MASK CANISTER

SIGNED _____ CHECKED _____

DATE _____ DATE _____

Gross Contact Likely

CONDITIONS characterized normally by "hand" operations where materials may be handled throughout the work period in large open containers without forced ventilation. Situations that exist in making emergency repairs in confined spaces and in taking care of spills are included in this category.

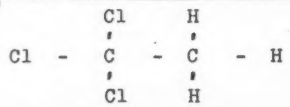
Occasional Daily Contacts

CONTACTS may be "gross," but occur only for short intervals occasionally throughout the work period. Ventilation may be provided for specific jobs. The potential severity of hazard will be less than *Gross Contact Likely* because the opportunities for contact will be less frequent and of shorter duration.

BIOCHEMICAL RESEARCH DEPARTMENT
THE DOW CHEMICAL COMPANY
MIDLAND MICHIGAN
DATA SHEET OF PROPERTIES, HEALTH HAZARDS, AND PRECAUTIONS FOR SAFE HANDLING OF MATERIALS

MOLECULAR FORMULA	CHEMICAL NAME
$C_2H_3Cl_3$	1,1,1-Trichloroethane
MOLECULAR WEIGHT / **INDUSTRIAL HYGIENE STANDARD**	**SYNONYMS**
133.5 / 500 ppm	Methyl Chloroform

STRUCTURAL FORMULA - EM COMPOSITION



PHYSICAL AND CHEMICAL PROPERTIES

BOILING POINT	EXPLOSIVE LIMITS (% BY VOL. IN AIR)	FLASH POINT	IGNITION TEMP.	MELTING POINT	VAPOR PRESSURE — Hg 25°C
74 °C 760 mm Hg.	--	None °F.	-- °C.	-32.7 °C.	Approx. 130

CORROSIVENESS (To Common Metals)	PHYSICAL STATE	COLOR
Corrodes aluminum and its alloys unless inhibited(chlorothene)	Liquid	Clear

CHEMICAL REACTIVITY	ODOR (Include Concentration in Air)
Relatively inactive.	Chloroform-like

STABILITY (To pH Change, Heat, Light)
HCl formed on standing

TOXIC PROPERTIES

TYPE OF CONTACT		CLASSIFICATION OF TOXIC PROPERTIES	
EYE		☒ May cause no response or no more than very slight to slight transitory pain and/or irritation of the eyelids.	☐ May cause some permanent loss of vision (this includes damage to cornea or internal injury which is incompletely healed in one week.)
		☐ May cause sufficient injury to the eye to result in loss of time from work. (This includes damage to the cornea which heals or nearly heals in a week and/or considerable conjunctival irritation with edema.)	☐ Vapor exposure may cause severe pain, lacrymation or serious injury to the eyes.
SKIN		☐ Single prolonged exposure (hours) causes no effect. Several repeated prolonged exposures may or may not cause the development of some slight irritation.	☐ Single short exposure (minutes) may cause considerable irritation and/or single prolonged or frequently repeated short exposures cause a burn and/or may cause systemic injury, even death.
		☒ Single prolonged exposure may cause some reddening of the skin. Repeated prolonged contacts may cause appreciable irritation, [illegible] and/or may cause [illegible] systemic injury due to absorption.	☐ An exposure rapidly causes severe burns and/or serious systemic injury, even death.
INHALATION	DUST OR MIST	☐ No systemic injury expected. No irritation to nose and throat in dusty or misty atmospheres.	☐ Dusty or misty atmosphere painful to nose and throat (intolerable to most people) and/or exposure may cause serious systemic injury.
		☐ Throat and nose irritation in a dusty or misty atmosphere is painful but not intolerable and/or prolonged or repeated exposures may cause systemic injury.	☐ Short exposure (minutes) may cause death or serious systemic injury.
	VAPOR	☐ Exposures do not cause any effects other than some very slight irritation or pain to the eyes or respiratory passages at the most.	☐ Exposures may cause extreme drowsiness, and/or serious systemic injury, and/or may cause intolerable irritation to the respiratory passages.
		☒ Single exposures exceeding 1/2 hour, or frequently repeated exposures of shorter duration, may cause slight anesthesia and/or slight systemic injury, [illegible] tolerable, [illegible] respiratory passages.	☐ Short exposures may cause unconsciousness, and/or serious systemic injury, including death.
		☐ Even very short exposure will cause serious systemic injury or death.	
INGESTION		☒ Amounts which may be swallowed incidental to industrial handling will not cause injury. However, if substantial quantities should be swallowed, more or less serious effects may occur.	☐ Amounts which may be swallowed incidental to industrial handling and use may cause serious injury.

COMMENTS

Minor Contact

OPERATIONS characterized by closed systems vented outside the work area. Personnel work around the equipment or in the immediate vicinity. Obvious opportunity for contact will not be evident normally.

No Contact

PROCESSES characterized by remote operation with equipment isolated from the area occupied by working personnel.

Precautionary Measures

HAVING established the above categories, precautionary measures appropriate to the likelihood of contact may be outlined by placing the proper letters in the spaces provided.

In developing this method of presenting toxicological and industrial hygiene information, it was believed that a correlation between the entries appearing under Toxic

	DEGREES OF EXPOSURE RELATED TO TYPES OF OPERATION		PRECAUTIONS (SEE CODE BELOW)				
			EYES	SKIN	INHALATION*		INGESTION
					DUST OR MIST	VAPOR	
I	NO CONTACT	Characterized by remote operation with equipment isolated from the work area. The persons entering isolated areas will require the personal protection outlined for IV below.	A	A		A	A
II	MINOR CONTACT	Characterized by closed systems with equipment vented outside the work area; instrument control; mechanical handling of materials in bulk. Examples are: continuous reactors, stills and filters; enclosed conveyors; ventilated packaging.	A	A		A	A
III	OCCASIONAL DAILY CONTACTS	Characterized by manual handling of materials in packages such as bags, drums and fiberpaks. Ventilation may be provided for specific jobs. Many batch operations fall into this category.	B	A		A	A
IV	GROSS CONTACT LIKELY	Characterized by hand operation. Examples are: Emergency repairs, cleaning equipment, cleaning filters, taking care of spills, packaging volatile or dusty materials without ventilation, wheeling and tray drying.	B	D		B	A

EYE CONTACT

- A No eye protection needed.
- B Use safety glasses without side shields.
- C Use safety glasses with side shields.
- D Use chemical workers goggles.
- E Use gas tight goggles or a full face gas mask.

SKIN CONTACT**

- A A bath and clean clothes once per week along with the usual washing at mealtimes should be adequate precautions.
- B Grossly contaminated clothing and shoes must be removed not later than the end of the work period and must be thoroughly cleaned before re-use.
- C Require shower at the end of the work period and clean clothing from the skin out at the start of each work day.
- D Clothing should be changed and skin washed promptly upon ~~unpleasantness~~ contact. Each use will require special consideration to determine suitable protective devices and standards of personal cleanliness.
- E Impervious clothing such as rubber boots, rubber aprons, and rubber gloves will be required. Specific items will be dictated as required by circumstance.

INHALATION

DUST OR MIST

- A No respiratory protection.
- B No protection required for exposure of thirty min. duration or less to obviously dusty atmospheres. Exposures of longer duration will require the use of a dust respirator bearing the approval of the U. S. Bureau of Mines for the use with toxic dusts.
- D Any exposure to obviously dusty atmospheres will require a dust respirator bearing the approval of the U. S. Bureau of Mines for use with toxic dusts.
- E Any exposure to dusty atmospheres will require the use of an airline respirator, blower mask, or Chemox mask.

VAPOR

- A No precautions necessary
- B No precautions necessary for single exposures of less than 1/2 hour. Longer single exposures, or frequently repeated exposures will require a gas mask or respirator equipped with appropriate canister.
- C No precautions necessary for single exposures of no more than ten minutes. Longer exposures either single or repeated, will require gas mask or respirator equipped with appropriate canister.
- D Gas mask with appropriate canister required at all times.
- E Evacuate area at once and enter only with airline respirator, blower mask or Chemox mask.

INGESTION

- A No unusual procedures required.
- E Food and tobacco should not be present in the work area. Hands and face should be washed before smoking and eating.

COMMENTS

**GOOD PRACTICE REQUIRES THAT GROSS AMOUNTS OF ANY CHEMICAL BE REMOVED FROM THE SKIN AS SOON AS IS PRACTICAL

*SUITABLE GAS MASK CANISTER

Organic vapor

SIGNED D. D. McCollister CHECKED H. R. Hoyle

DATE 10-11-55 DATE 10-13-55

TABLE II.
BROMINE

Degrees of Exposure Related to Types of Operation	Precautions Eyes	Skin	Inhalation Dust or Mist	Vapor	Ingestion
I No Contact	A	A		A	A
II Minor Contact	C	D		C	A
III Occasional Daily Contacts	E	E		D	A
IV Gross Contact Likely	E	E		E	A

Properties on the front side with Precautions on the reverse would aid in maintaining a consistency in evaluating a large number of materials.

Thus, the description corresponding to the letters which appear in the boxes opposite *Gross Contact Likely* usually will be those relating directly to the description of toxic properties in the same relative position on the front of the form.

For example, under *Eye Contact*, item "C" (use safety glasses with side shields) is recommended for those materials which are classified as "May cause sufficient injury to the eye to result in loss of time from work."

The precautionary statements and suggestions for personal protective requirements are those which have become more or less routine in operations within The Dow Chemical Company. Consideration has been given to the standards of personal cleanliness that may be necessary to minimize hazard in each specific circumstance, and to the use of suitable protective devices such as eye glasses or goggles, gas masks or impervious clothing.

After the precautions have been indicated for eyes, skin, inhalation and ingestion in the lines provided across from *Gross Contact Likely*, the precautions may be modified vertically in each column stepwise according to type of operation (see example, 1,1,1-trichloroethane).

For a material which may present a much greater hazard than 1,1,1-trichloroethane, a typical tabulation is given in Table II. It takes but a glance at the "Precautions" tabulation to obtain an over-all impression of the relative hazard that may be encountered in handling a particular material in a given manner.

Practical Use by Supervisory Personnel

Category of Operation

THE COMPILATION of information appearing in this "Data Sheet" has been intended primarily for use by the technically trained supervisor. The first decision to be made by such an individual is which of the four categories of operation describes his proposed utilization of the material in question. Once this decision is made, he notes the precautions and personal protective requirements indicated by the letters in the appropriate boxes.

Modification of Hazard

THE HAZARD resulting from any proposed use of a material can be modified by equipment or operational changes which tend to reduce the likelihood of contact. Thus, if the first manner of use proposed for a material requires safety measures or devices under the circumstances objectionable to the supervisor and his men, he may wish to plan his operation so that it will fall into a more suitable category. Conversely, it may also be possible for the supervisor to plan simpler engineering design than originally intended if he chooses to reduce the likelihood of contact by the use of suitable personal protective devices.

At first thought, the use of personal protective devices is always attractive since it offers something that can be done at once without great monetary expense. However, experience indicates that most protective devices are uncomfortable to wear and, therefore, are acceptable to workmen only on an emergency basis. There is also the possibility that protective devices will not be worn correctly or that malfunction will occur with serious consequences. On the other hand, requirements of unusual standards of personal cleanliness usually are more acceptable to workmen.

Summary and Conclusions

A METHOD has been outlined for the presentation of properties, health hazards and precautions for safe handling of materials. It is an attempt to satisfy a need not only for a convenient and practical means for describing the toxic properties of ma-

terials but also for a way to interpret these properties in terms of the hazard resulting from their use in specific circumstances.

In practice within The Dow Chemical Company, the Data Sheet has proven flexible and adaptable. The more extensive the toxicological data the more confidence is placed in the classification of toxic properties. However, using good judgment the experienced toxicologist can interpret so-called "range-finding" data, data from other laboratories, or data from the literature. Then, considering relevant physical and chemical properties he may arrive at an appropriate classification of toxic properties.

The compilation has been designed primarily to be placed in the hands of a technically trained supervisor in charge of industrial operations. To the knowledge of the authors, this is a first attempt to provide such an individual with a description of health hazards in terms of types of operating procedures and corresponding precautionary measures and requirements for personal protection.

To the Industrial Hygienist, it has proven particularly beneficial when dealing with the individual who insists upon considering a definition of toxic properties to be synonymous with a description of the absolute hazard presented by a material regardless of the circumstance of use.

✦ News of Local Sections

Chicago

THE first meeting of the 1957-1958 year was held September 11. LLOYD GORDON discussed industrial hygiene activities at the Zurich-American Insurance Companies.

At the October 2nd meeting, HAROLD HOYLE of the Dow Chemical Company spoke on "Control of Health Hazards Which May Result From the Use of Chlorinated Solvents." MR. HOYLE used slides in his interesting and informative presentation.

RALPH. W. WOIDA, Superintendent of Building Maintenance, Allis-Chalmers Manufacturing Company, spoke on "Modern Sanitation Practices in Industry" at the meeting on November 6. MR. WOIDA emphasized the assistance given by their industrial hygiene division in evaluating maintenance products from the health and safety standpoint.

Several members attended the Annual Merit Awards Dinner of the Chicago Technical Societies Council held November 7, at the Furniture Club. The Chicago Section of AIHA is a member of the Council.

Northern California

THE 48th meeting of the Northern California section was held September 24. BENJAMIN LINSKY, Control Officer of the Bay Area Pollution Control District, spoke on "The Role of the Industrial Hygienist in Air Pollution Control Work." He emphasized the need for hygienists and air pollution control personnel to work together so that in eliminating a hazardous condition within the plant a pollution problem is not created outside the plant.

At the meeting of November 4, HERBERT E. STOKINGER, Ph. D., Toxicologist, U. S. Public Health Service, gave an interesting discussion on the subject, "Early Indicators of Response to Toxic Agents."

Southern California

NELS SODERHOLM, Sales Engineer, American Air-Filter Co., Inc., was the speaker at the September 12 meeting. His subject was "Clean Air For the Atomic Energy Commission."

The Southern California section participated in the First Annual Western Occupational Health Conference held at the Biltmore Hotel, Los Angeles, October 4, 5 and 6. A luncheon meeting of the Northern and Southern California Sections, and the American Conference of Governmental Industrial Hygienists was held October 4.

At the meeting November 14, C. MERSKOETTER of the Mine Safety Appliances Company spoke on "Recent Advances in Personnel Respiratory Protection."

HYGIENIC GUIDE SERIES

METHYL ALCOHOL (Methanol)

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 200 parts of vapor per million parts of air by volume (ppm).[1]

(1) *Basis for Recommendation:* Human experience and animal experimentation.[3,11,12]

B. SEVERITY OF HAZARDS:

(1) *Health:* Moderate for acute and chronic exposures. Inhalation of very high concentrations produces central nervous system depression and optic nerve damage. Recovery is slow and delayed death may occur. These more serious effects and deaths following inhalation are reported chiefly in the older literature. Lower concentrations may cause headache, dizziness, weakness or fatigue, gastrointestinal or visual disturbances. Many deaths or permanent eye damage have been reported from ingestion. Amounts in the neighborhood of 3-4 ounces may be fatal.[2,5] May be absorbed through the skin.

(2) *Fire:* High. Explosive limits are 6.0 to 36.5% by volume. Ignition temperature is 470°C. Flash point (closed cup) is 12°C (54°F).

C. SHORT EXPOSURE TOLERANCE: Dogs exposed to 10,000 ppm repeatedly for brief periods developed no abnormalities.[10] On the basis of experimental human exposures, it has been calculated that repeated eight-hour exposure to 3,000 ppm will lead to increasing methanol concentrations in the body.[7] Workers with repeated short exposures to 400 to 500 ppm and for shorter periods (½ hour or less) to 1,000 to 2,000 ppm have not shown detectable effects.[12]

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Delayed deaths following narcosis from acute exposures of animals of various species occur at concentrations from 30,000 to 100,000 ppm.[2] Exposure of humans for part of a working day to 40,000 ppm may cause delayed death.[3]

II. Significant Properties

A clear, colorless liquid with a faint odor similar to ethyl alcohol.

Chemical formula:	CH_3OH
Molecular weight:	32
Specific gravity:	0.792 at 20°C/4°C
Boiling point:	64.7°C
Vapor pressure:	92 mm Hg at 20°C
Relative vapor density:	1.11 (air = 1)
At 25° C and 760 mm Hg, 1 ppm of vapor:	0.001309 mg/liter
1 mg/liter of vapor:	764 ppm
Solubility:	In water, alcohols, ketones, esters and halogenated hydrocarbons.

III. Industrial Hygiene Practice

A. RECOGNITION:

(1) Odor and irritation occur only at high concentrations. Odor is faint at 2,000 ppm.

(2) Has wide use as a solvent, especially in the paint and varnish, dye manufacturing, printing, photographic, and plastics industries. Spirit duplicating fluids may be a source of exposure.[8] Constituent of some antifreezes.

B. EVALUATION OF EXPOSURES:

(1) *Chemical:* Collect in distilled water, oxidize with permanganate and develop color with Schiff's reagent or chromotropic acid.[3,6]

C. RECOMMENDED CONTROL PROCEDURES:

Maintain workroom atmospheric concentrations below 200 ppm by adequate ventilation, temperature control or enclosure. Because of lack of warning properties, routine air analyses are advisable wherever large quantities are handled, or in confined spaces. Substitution of other less toxic alcohols may be indicated in some cases. Skin exposure should be avoided. Control ventilation is usually necessary in any small work area, or, in lieu of this, adequate personal respiratory protection.

IV. Specific Procedures

A. FIRST AID: Remove from exposure, wash the affected skin areas, irrigate eyes with water. Keep patient quiet, institute artificial respiration if breathing has ceased, obtain medical aid promptly.

B. SPECIAL MEDICAL PROCEDURES: Persons with pre-existing central nervous system disease or significantly decreased visual acuity should not be allowed to work where a hazard of major acute exposure exists or where there can be substantial repeated exposures. Medical treatment of acute overexposure should consist of supportive therapy. Direct alkali treatment of acidosis is indicated if such exists. There is some evidence that the simultaneous ingestion of ethyl alcohol slows down the oxidation of methanol to formic acid to a point where the hazard from the latter substance becomes less.[8,9] Methyl alcohol in blood or urine can be measured by method of Stratton,[13] or Feldstein.[4]

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 16:262, 1957.
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PHENOL

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 5 parts of vapor per million parts of air, by volume (ppm).[1]

(1) *Basis for Recommendation:* Animal studies and human experience.

B. SEVERITY OF HAZARDS:

(1) *Health:* Moderate for chronic. Moderate to severe for acute exposure. Ingestion of phenol or cresol will induce intense burning of mouth and throat, followed by marked abdominal pain and distress. Cyanosis, muscular weakness, or tremors and convulsions followed by collapse may occur a few minutes after the material is swallowed. Local contact with the skin and mucous membranes will induce gangrene and corrosion if the exposure is sufficiently severe. All of the systemic effects listed under "ingestion" may be induced if the skin area exposed is large, the phenol solution a concentrated one, and the period of exposure more than a minute or two. It is doubtful whether chronic poisoning from inhalation occurs to any extent in industry. Acute vapor exposures may cause symptoms of the same type as seen following acute exposures to the skin. Severe dermatitis may occur from even dilute solutions.

(2) *Fire:* Moderate. Flash point (closed cup) is 80° C (175° F).

C. SHORT EXPOSURE TOLERANCE: See above for skin exposure.

D. ATMOSPHERIC CONCENTRATION IMMEDIATELY HAZARDOUS TO LIFE: Not known. Inhalation of vapor concentrations of 26-52 ppm by guinea pigs caused distress and

illness after 20 successive periods of exposure (7 hrs/day) accompanied by postmortem evidence of acute toxicity to lung, heart, liver, and kidney.[3] Rabbits, and particularly, rats, were less sensitive to injury.[4]

II. Significant Properties

A white solid with a characteristic odor.

Chemical formula:	C_6H_5OH
Molecular weight:	94
Specific gravity:	1.072
Melting point:	41° C
Boiling point:	182° C
Vapor pressure:	100 mm Hg at 120.2° C
Relative vapor density:	3.2 (air = 1)
At 25° C and 760 mm Hg,	
1 ppm of vapor:	.0038 mg/liter
1 mg/liter:	260 ppm
Solubility:	Partly soluble in water. Miscible with alcohol and most organic solvents.

III. Industrial Hygiene Practice

A. RECOGNITION: By its characteristic odor. Major uses are the chemical, drug, and plastics industries.

B. EVALUATION OF EXPOSURE:

(1) *Instrumentation:* None available.

(2) *Chemical Method:* Absorption in dilute alkali, followed by colorimetric determination with diazotized p-nitroaniline reagent,[6] or absorption in spectrograde alcohol with direct determination by ultraviolet spectrophotometry.

C. RECOMMENDED CONTROL PROCEDURES: Maintain workroom atmospheres below 5 ppm by process enclosure and/or ventilation. Avoid skin contact.

IV. Specific Procedures

A. FIRST AID: Remove from contaminated area. If skin or eyes are affected, wash with water; if skin area is large, remove clothes promptly under shower. In oral poisoning, quickly induce vomiting if individual is conscious.[5]

B. SPECIFIC MEDICAL PROCEDURES: Treatment is largely symptomatic. If vomiting has not been effectively induced in oral poisonings, gastric lavage should be used. Individuals with evidence of liver or kidney disease or with known skin sensitivities to phenol should not be assigned to exposure. Determination of free and conjugated phenol in the blood and urine may be of some use in estimating exposure.[2]

NOTE: Dr. William B. Deichmann (University of Miami) assisted the Hygienic Guides Committee in the preparation of this Guide.

V. Literature References

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TOLUENE 2,4 DIISOCYANATE
(Tolylene 2,4 diisocyanate, TDI)

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 0.1 parts of vapor per million parts of air by volume (ppm).[1]

(1) *Basis for Recommendation:* Animal experimentation,[8] and industrial experience.[5]

B. SEVERITY OF HAZARDS:

(1) *Health:* Extra-hazardous for acute and chronic vapor exposures. Low oral toxicity. Primary irritant of gastrointestinal tract, eyes, skin and respiratory tract. Repeated exposure may produce an asthma-like syndrome.[3,6,7] Skin sensitization in animals has been demonstrated.[8]

(2) *Fire:* Not known, but probably is low.

C. SHORT EXPOSURE TOLERANCE: Not known. Is irritating to the nose and throat at 0.5 ppm.

D. ATMOSPHERIC CONCENTRATION IMME-

DIATELY HAZARDOUS TO LIFE: 600 ppm for six hours is lethal to rats.[8]

II. Significant Properties

Toluene 2,4 diisocyanate as prepared, is a water white liquid which turns straw-colored on standing.[2]

Chemical formula:	$CH_3C_6H_3$ $(NCO)_2$
Molecular weight:	174
Specific gravity:	1.21 at 28°C
Relative vapor density:	6.0 (air = 1)
Boiling point:	250°C at 760 mm Hg.[2]
Vapor pressure:	Approx. 1 mm Hg at 80°C[2]
Odor threshold:	0.4 ppm (50% of subjects)[8]
At 25° C and 760 mm Hg, 1 ppm of vapor:	0.00712 mg/liter
1 mg/liter of vapor:	140.5 ppm
Solubility:	In acetone, ethyl acetate, carbon tetrachloride, kerosene, toluene and nitrobenzene.

III. Industrial Hygiene Practice

A. RECOGNITION: By its odor and irritant effects. Used in the manufacture of polyurethane foams, coatings, and castings.

B. EVALUATION OF EXPOSURES:

(1) *Chemical:* Colorimetric determination after collection in sodium nitrite, or ethylene glycol monoethyl ether, and determination by the method of Ranta,[8] or Marcali.[4]

C. RECOMMENDED CONTROL PROCEDURES: Enclosure of processes with adequate ventilation. In spray and inadequately ventilated applications, personal respiratory protection may be necessary.

IV. Specific Procedures

A. FIRST AID: Removal from environment following vapor irritation. Following liquid contamination, wash all surfaces thoroughly.

B. SPECIAL MEDICAL PROCEDURES: Preplacement examinations to prevent exposure of employees with chronic respiratory illnesses and respiratory allergies.

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 16:265, 1957.
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ETHYL BENZENE (Phenylethane)

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 200 parts of vapor per million parts of air (ppm).[1]

(1) *Basis for Recommendation:* Human and animal studies.[2,5,6,7]

B. SEVERITY OF HAZARDS:

(1) *Health:* Moderate for both acute and chronic exposure. Absorption is chiefly by inhalation. Eye irritation begins with most humans at about 200 ppm. High concentrations produce profuse lachrymation, nasal irritation and narcosis.[2] It is considered the most severe skin irritant of the benzene series.[2] It does not have the deleterious effect on the blood as does benzene.[3] No report of injury from its industrial use has been recorded. Chronic vapor inhalation studies, using various animal species, have shown no effects, other than slight increases in liver and kidney weights in rats, using seven-hour daily exposures of 400 ppm for six months.[6]

(2) *Fire:* High. Flash point is 15°C (59°F) (Closed cup).

C. SHORT EXPOSURE TOLERANCE:[7] Not known for man. Exposure of guinea pigs for 60 minutes to atmospheric concentrations of 7000 ppm produced no deaths, and 3000 ppm for 60 minutes produced no serious symptoms. Eye irritation and dizziness

occur in advance of serious response from a single exposure. Concentration of 2000 ppm probably not tolerated by humans.

D. ATMOSPHERIC CONCENTRATIONS IMMEDIATELY HAZARDOUS TO LIFE: Unknown. Impossible to obtain a sufficiently high concentration in air at room temperature to kill guinea pigs in from 30 to 60 minutes.[7] Saturated air at 20°C contains less than 2% vapor.

II. Significant Properties

A flammable, colorless, odorous liquid.

Chemical formula:	$C_6H_5C_2H_5$
Molecular weight:	106
Specific gravity:	0.8669 (20°C/4°C)
Boiling point:	136.2°C
Relative vapor density:	3.66 (air = 1)
Vapor pressure:	15.3 mm of Hg at 20°C
Solubility:	In most organic solvents.
At 25° C and 760 mm Hg,	
1 ppm of vapor:	0.00434 mg/liter
1 mg/liter of vapor:	230.7 ppm

III. Industrial Hygiene Practice

A. RECOGNITION: Used in organic syntheses, as a solvent, and as a diluent in lacquers. Some commercial petroleum solvents may contain appreciable quantities of ethyl benzene.

B. EVALUATION OF EXPOSURES:

(1) *Instrumentation:* Direct determination by the Davis Vapotester Model M-6 (Davis Emergency Equipment Company, Newark, N. J.), or the MSA Combustible Gas Detector, Model 40 (Mine Safety Appliances Company, Pittsburgh).

(2) *Chemical method:* The vapors may be collected in a gas sampling bottle, evacuated bulb, or by absorption in nitric acid, and determined by the butanone method described for toluene.[4] (A green color is produced). In the absence of other vapors it may be absorbed on activated charcoal or silica gel and determined by weighing.

C. RECOMMENDED CONTROL PROCEDURES: Maintain workroom atmosphere below 200 ppm by means of process enclosure and/or ventilation. Prevent contact with the liquid through the use of protective clothing and chemical-type goggles.

IV. Specific Procedures

A. FIRST AID: Remove from exposure; remove contaminated clothing, cleanse skin, eys, etc. Artificial respiration should be started at once if breathing has stopped.

B. SPECIFIC MEDICAL PROCEDURES:

(1) *Preplacement:* Complete clinical and laboratory examinations are desirable for proper placement.

(2) *Periodic:* Clinical and laboratory studies should be done. Absorption of ethyl benzene is reported to result in an increase in the amount of hippuric acid in the urine.[2]

V. Literature References

1. American Conference of Governmental Industrial Hygienists: *AMA Arch. of Ind. Health*, 16:262, 1957.

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PYRIDINE

I. Hygienic Standards

A. RECOMMENDED MAXIMUM ATMOSPHERIC CONCENTRATION (8 hours): 10 parts of vapor per million parts of air by volume (ppm).[1]

(1) *Basis for Recommendation:* Human experience in industry.[3,4]

B. SEVERITY OF HAZARDS:

(1) *Health:* Moderate for acute or repeated exposures. In higher concentrations, it is a narcotic. It has an irritating effect and a

nauseating, unpleasant odor. Liver and kidney damage have been produced in animals and man from oral administration.[2,7] Lower concentrations in air give rise to nausea, headache, insomnia, nervous symptoms, low back or abdominal discomfort with urinary frequency. It is absorbed through the skin.[4] May cause skin irritation.

(2) *Fire:* High. Explosive limits are 1.8 to 12.4% by volume. Flash point (closed cup) is 20°C (68°F).

C. SHORT EXPOSURE TOLERANCE: Odor becomes objectionable to most unacclimatized people at 10 ppm and very disagreeable at 30 ppm. Exposures averaging 125 ppm, four hours per day for one to two weeks give rise to symptoms.[4]

D. ATMOSPHERIC CONCENTRATIONS IMMEDIATELY HAZARDOUS TO LIFE: Unknown. Death resulted in rats exposed to 23,000 ppm (calculated) for 1½ hours,[4] and to 4,000 ppm for four hours.[8]

II. Significant Properties

Pyridine is a colorless, basic liquid with a characteristic unpleasant odor.

Chemical formula.	C_5H_5N
Molecular weight:	79
Specific gravity:	0.982 (20°C/4°C)
Boiling point:	115.6°C (760 mm Hg)
Vapor pressure:	20 mm Hg, at 25°C
Relative vapor density:	2.72 (air = 1)
At 25° C and 760 mm Hg, 1 ppm of vapor:	.00323 mg/liter
1 mg/liter of vapor:	309 ppm
Solubility:	In water, alcohols, ether, chloroform. Insoluble in aqueous alkali solutions.

III. Industrial Hygiene Practice

A. RECOGNITION:

(1) By its characteristic odor.

(2) Increasing use as a solvent in chemical processes and syntheses. Used as a denaturant for alcohol, in the dye industry, in manufacture of some explosives, pharmaceuticals, textiles, paint.

B. EVALUATION OF EXPOSURES:

(1) *Odor:* Easily detectable at less than 1 ppm. It is very disagreeable to most individuals at 30 ppm, but odor is an unreliable guide at concentrations exceeding 5 ppm. Olfactory fatigue occurs quickly.[6]

(2) *Instrumentation:* No direct reading instruments available. Determination by ultraviolet spectrophotometry at 256 millimicrons after collection in specially denatured alcohol (formula 3A)[6] or with the mass spectrometer.[4]

(3) *Chemical:* Collection in known volume of 0.1 *N* sulfuric acid and back titration of excess with standard alkali.[5] This probably is useful only for high concentrations.

C. RECOMMENDED CONTROL PROCEDURES: Maintain workroom atmospheric concentrations below 10 ppm by process enclosure and/or ventilation. Exhaust air should be disposed of in such a way as to not cause a public nuisance. Use personal protective equipment as required. Avoid skin contact.

IV. Specific Procedures

A. FIRST AID: Remove from exposure, wash skin thoroughly with large amounts of water and irrigate eyes with water for at least 15 minutes.

B. SPECIFIC MEDICAL PROCEDURES: Persons with pre-existing renal disease or central nervous system disorders should probably be excluded from work where repeated high exposures can occur. It would be desirable to follow individuals with repeated substantial exposures by complete periodic clinical examination. Persons who have had large overexposures should be followed carefully for abnormalities in liver, central nervous system, or renal function.

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Because of space limitations, it is impossible to list all methods of exposure evaluation. The selections have been made on the basis of current usage, reliability, and applicability to the usual industrial type of exposure. Any specific evaluation and/or control problem will involve professional judgment. This can best be done by professional industrial hygiene personnel.

Respiratory protective devices are commercially available. Their use, however, should be confined to emergency or intermittent exposures and not relied upon as primary means of hazard control.

A relative scale is used for rating the severity of hazards: nil, low, moderate, high, and extra hazardous.

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Erratum

THE HYGIENIC GUIDE for Ethyl Alcohol which appeared in the March, 1956 issue of the AIHA Quarterly, erroneously listed the vapor pressure to be 20° C 11 mm Hg. This should have been 42.3 mm Hg.

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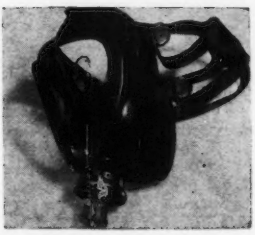

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CARBIDE & CARBON CHEMICALS CORP.
CUMMINS ENGINE CO.
DOUGLAS AIRCRAFT
DOW CHEMICAL COMPANY
GENERAL ELECTRIC CO.
NORTH AMERICAN AVIATION, INC.
NORTHROP AIRCRAFT, INC.
REPUBLIC AVIATION CORP.
SCOTT PAPER CO.
UNITED GAS PIPE LINE CO.
and GOVERNMENT AGENCIES

. . . this list runs on and on — and serves to point out the confidence in FLENTS held by so many industrial users, since 1927!

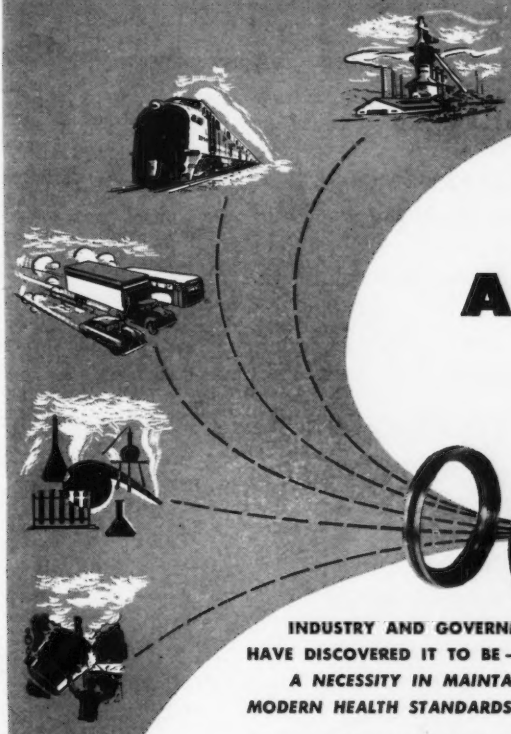
In the best interests of your firm and employees, investigate the use of FLENTS, without delay!

FREE . . . Test FLENTS in your own plant. Send for Free samples today.

FLENTS **PRODUCTS COMPANY, Inc.**
Dept. I-127, 103 PARK AVENUE · NEW YORK 17, N.Y.

* Reg. U.S. Pat. Office

TO COMBAT AIR POLLUTION . . .



Staplex TRADE MARK

HI-VOLUME AIR SAMPLER

INDUSTRY AND GOVERNMENT HAVE DISCOVERED IT TO BE—
A NECESSITY IN MAINTAINING MODERN HEALTH STANDARDS

The STAPLEX HI-VOLUME AIR SAMPLER has proven to be a basic instrument in combating and controlling air pollution. Time-tested . . . excellent for both indoor and outdoor sampling . . . this sampler accomplishes in 10 minutes what previous units required 36 hours to do.

Accurately samples large volumes of air containing particulate matter as small as 1/100th of a micron in diameter through use of filter papers. Standard filter paper 4 inches in diameter. 6" x 9" and 8" x 10" adapters available. Other sizes to order.

Hundreds now in use by Industry and all types of government health agencies, Municipalities, Insurance Companies, etc. to accurately measure factory health hazards, atmospheric conditions, smoke abatement, smog, for mine inspections, and many other applications.

Write for NEW brochure. BULLETIN 1-H 4, on Air Samplers.

THE Staplex COMPANY
AIR SAMPLER DIVISION
777-A Fifth Avenue, Brooklyn 32, N.Y.

NAME .....
COMPANY .....
ADDRESS .....

12-57

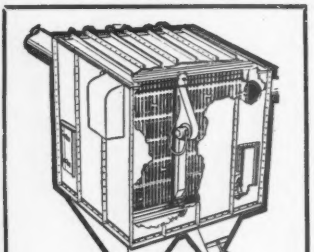
Pangborn Dust Control
can cut operating costs 5 way

Pangborn Dust Collectors trap industrial dusts at the source of origin. By doing so, they cut plant operating costs five ways. Pangborn Dust Control:

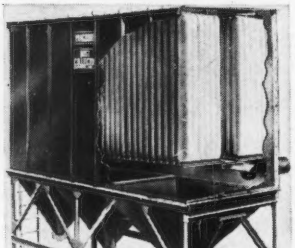
1. Cuts machinery maintenance costs. Eliminates abrasive wear of dust —saves parts and labor costs, downtime.
2. Cuts housekeeping costs. Cleaning and painting are not required as often.
3. Reclaims material. Valuable dust can be re-used or sold as a by-product.
4. Increases employee efficiency. Production goes up when personnel works in dust-free atmosphere.
5. Cuts heating costs. Many plants recirculate the already-heated, cleaned air.

In addition, Pangborn Dust Control guards product quality, protects employees' health, improves morale within the plant and community relations outside.

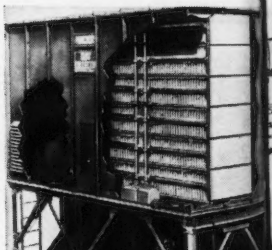
Which Pangborn Dust Collector do you need?



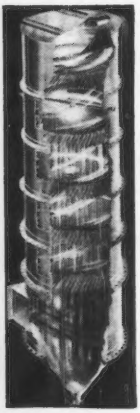
For automatic, *continuous* operation, the Pangborn Self - Cleaning Collector — combining the proved efficiency of the cloth screen collector with continuous operation, uniform air flow.



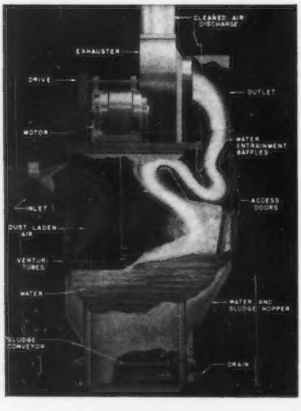
Also for dry dusts, the Pangborn Cloth Bag Collector—an efficient, economical method of dust control. Its simplified design and construction involves a minimum of parts. Easily inspected and maintained.



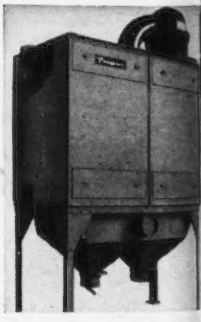
For fine, dry dusts, the Pangborn Cl Screen Collector—accomplishes hi recovery at low cost; easily mai tained and gives maximum clot area for the space available.



The Pangborn Centrifugal Wet Collector—for hot, moist, inflammable, abrasive, corrosive or obnoxious dusts. A tower-type counter-flow construction gives high-efficiency performance in small space. Operating cost is low.



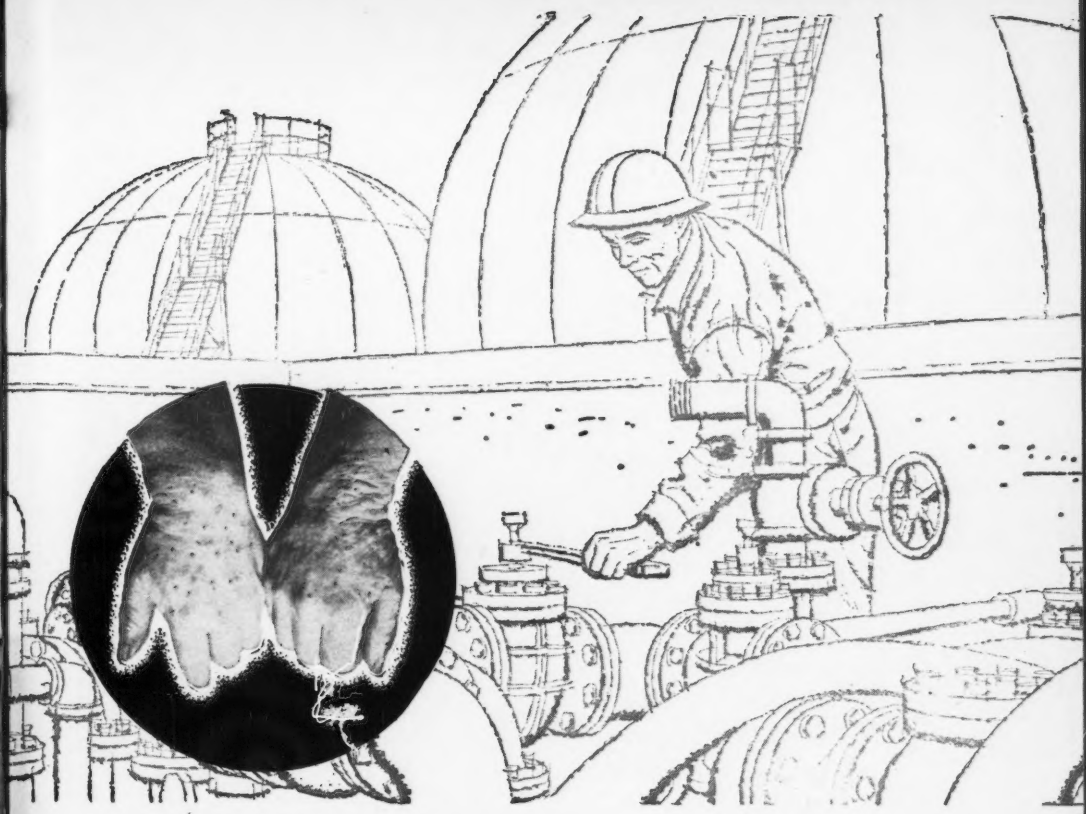
The Pangborn Ventrijet Wet Collector—also for dusts that a dry type collector cannot handle. A compact, self-contained unit with low headroom. Inexpensive to maintain and operate, its ease and economy of installation recommend its use in many cases.



For small volume applications, th Pangborn Unit Type Collector— a self-contained unit, shipped assembled ready for installation. Seven sizes, ranging fro 200 to 1,000 sq. ft. of cloth area

NOTE: Bulletins are available on all Pangborn Dust Collectors. For your copy or more details, write PANGBORN CORP., 4500 Pangborn Blvd., Hagerstown, Md. *Manufacturers of Dust Control and Blast Cleaning Equipment.*

Pangborn
CONTROLS DUST



Why **DERMATITIS** is a needless penalty

Dermatitis caused by industrial materials such as chemicals, oils and abrasives can be prevented. Simply. Inexpensively. With a basic program that safeguards and improves the hygiene of workers — the West Program of Dermatitis Prevention and Control.

How does it work?

No contributing source of dermatitis is overlooked. Specially formulated handcleaners insure personal cleanliness. Antiseptic creams help protect exposed skin areas. "Vinylite" aprons and armguards prevent clothing contamination. Other specialties protect against bacteria infections.

Workers are protected against physical discomfort, lowered morale and lost time.

Management is protected against the costs of medical care, absenteeism, replacement training, sacrificed quality and lost production.

Why not discuss the West Program of Dermatitis Prevention and Control with one of our specialists? His recommendations will help you eliminate the needless penalty of dermatitis. No obligation of course. Just send the coupon.

Programs and Specialties for Effective Sanitation and Preventive Maintenance

WEST CHEMICAL PRODUCTS INC.

WEST DISINFECTING DIVISION

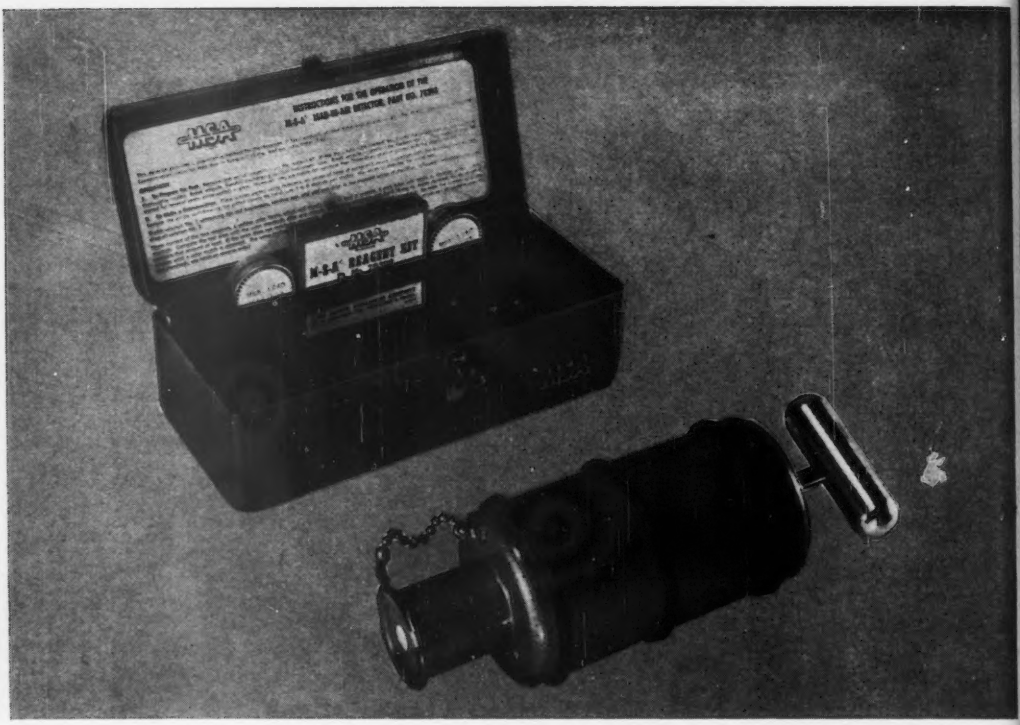
WEST CHEMICAL PRODUCTS INC., 42-16 West Street, Long Island City 1, N. Y.
Branches in principal cities • In Canada: 5621-23 Casgrain Ave., Montreal

☐ Please send your 24 page booklet "The Control of Dermatitis in Industry."
☐ Please have a West representative telephone for an appointment.

Name .....

Position .....

Mail this coupon with your letterhead to Dept.



Compact aluminum case suspends at waist height from shoulder straps. When open, lid serves as small work-shelf.

New M-S-A® Lead-In-Air Detector Kit determines and measures air-borne lead dusts and fumes

There's a quick, effective way to protect workers in lead exposures. Use an M-S-A Lead-In-Air Detector Kit.

M-S-A has assembled a field kit for detecting and measuring air-borne lead contamination. The apparatus in this kit permits determination of the weight of lead present in a measured volume of air by use of a simple spot test color comparison. Concentrations of lead well below and above the Maximum Allowable Concentration of .15 milligrams per cubic meter are readily measured.

Proper ventilation *may* eliminate the danger from small concentrations of invisible lead dusts and fumes. However, a constant check must be kept on its effectiveness to insure an atmosphere that is safe for continuous, prolonged occupation.

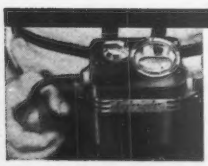
That's why the M-S-A Lead-In-Air Detector Kit makes so much sense as a safety measure. Write for new bulletin for operating instructions and details.

MINE SAFETY APPLIANCES COMPANY

201 North Braddock Avenue, Pittsburgh 8, Pennsylvania

At your Service: 83 Branch Offices in the United States and Canada

MSA
SAFETY EQUIPMENT HEADQUARTERS



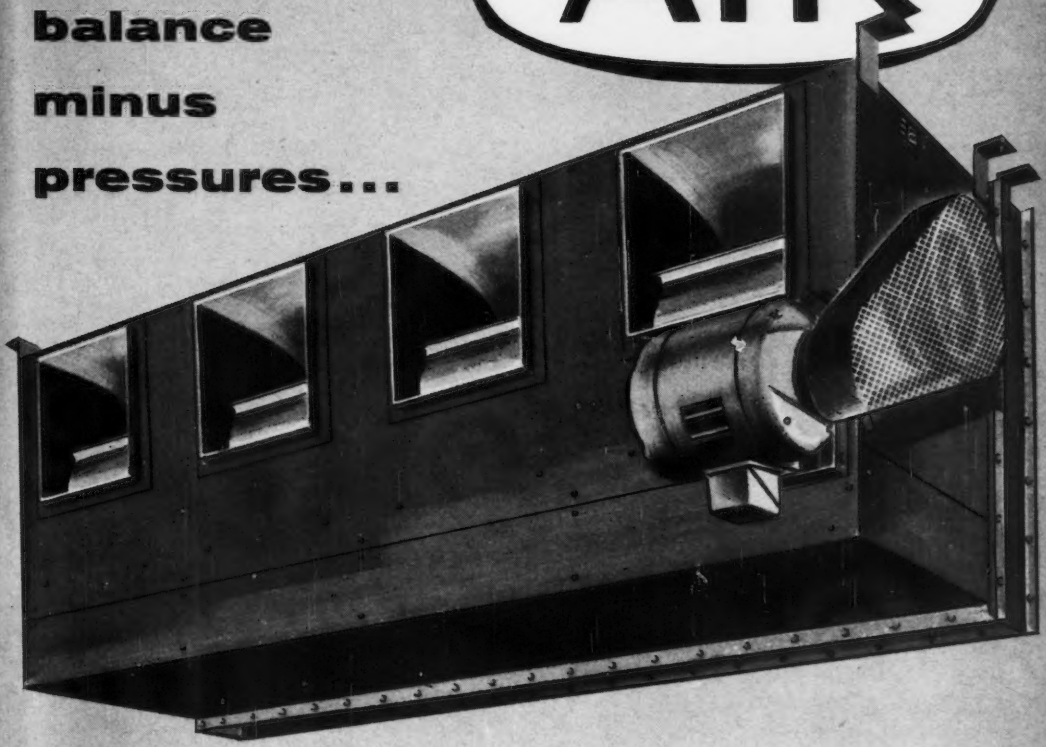
M-S-A EXPLOSIMETER
Detects and measures explosive concentrations of gases and vapors in atmosphere. One-hand operation. Easy-to-read dial.

M-S-A COLORIMETRIC INSTRUMENTS
Sniff out suspected areas that may contain harmful and dangerous toxic gas concentrations. Simple, quick, accurate.

M-S-A GASCOPE
Single, dual-scale meter indicates full range of combustible gas concentrations. Offers accuracy, speed and simplicity in leak detection.

...to replace exhausted air and balance minus pressures...

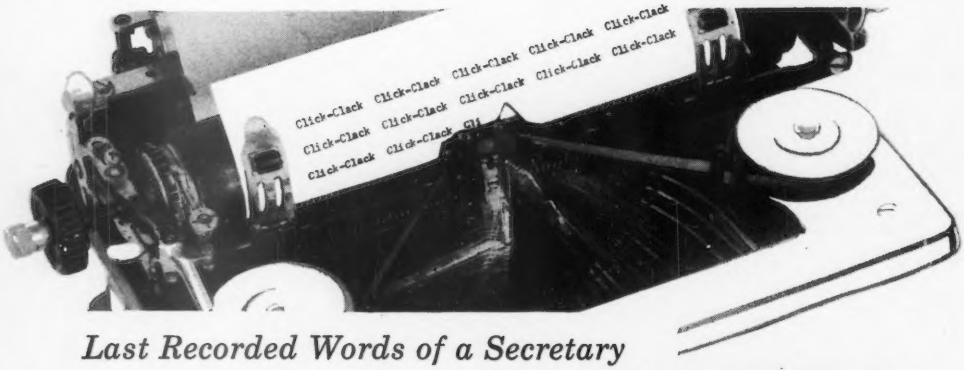
Make-Up AIR



Where gases, dust and fumes are removed by exhaust fans in large volumes, depleting the air supply within the building and creating a minus pressure, consider the possibilities of the Make-Up AIR. These compact ceiling-suspended units replace the air from the outside in an even and constant flow, without drafts or noise. Warm, clean air is delivered in definite known quantities to balance the known loss, correcting drafty conditions and uncontrolled infiltration. All units are equipped with vertical tube coils providing quick removal of condensate. Complete details in bulletin 568.

nyb **THE NEW YORK BLOWER COMPANY**

SALES OFFICES: 3165 SOUTH SHIELDS AVENUE • CHICAGO 16

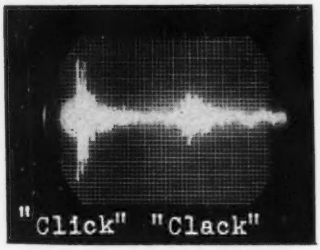

Click-Clack Click-Clack Click-Clack Click-Clack Click-Clack
Click-Clack Click-Clack Click-Clack Click-Clack Click-Clack
Click-Clack Click-Clack Cli

Last Recorded Words of a Secretary about to Succumb to Typewriter Nerves*

A well known contributor to office noise is the nerve-jangling clack of typewriters. Aware of this, Underwood Corporation's General Research Laboratory in Hartford, Connecticut began a program of measurement and interpretation of business-machine noises well over twenty years ago.

Noises from machines such as typewriters are made up of a series of short-duration bursts of sound. Sound-level meters and spectrum analyzers by themselves are inadequate for measuring these extremely short impact noises. These measurements *can* be made with the General Radio Impact-Noise Analyzer, the only commercially available instrument designed expressly for the direct measurement of impact noises. Designed as an accessory to the Type 1551-A Sound-Level meter, the Analyzer permits the determination of both sound level and time duration of impact noises. Underwood found that the Impact-Noise Analyzer suited their measurement needs perfectly, and with its help was able to make the "Golden Touch" typewriter the quietest typewriter they have ever built.

*This malady is closely akin to drop-hammer wheezy, punch-press blues, and air-hammer palsy.



Oscillogram of a typical typewriter noise. First impact occurs when type bar strikes the ribbon — peak value is approximately 115 db and lasts about 3 milliseconds. A second peak occurs some 50 milliseconds later when the type bar returns to its rest position.

G-R Type 1556-A Impact-Noise Analyzer, $210

. . . Measures Three Essential Characteristics of Impact Noises

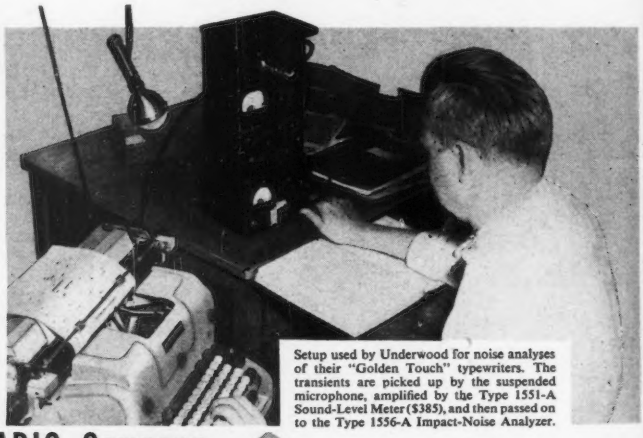
"Peak-Reading" Measurement: indicates the maximum instantaneous level reached by the noise.

"Time Average": a measure of the average level maintained by the noise over a selected period of time.

"Quasi Peak": a continuously indicating measure of the peak sound level.

An electrical storage system is provided, making possible measurement of all three of the above characteristics for any single impact.

Write for Complete Information



Setup used by Underwood for noise analyses of their "Golden Touch" typewriters. The transients are picked up by the suspended microphone, amplified by the Type 1551-A Sound-Level Meter ($385), and then passed on to the Type 1556-A Impact-Noise Analyzer.

GENERAL RADIO Company

275 Massachusetts Avenue, Cambridge 39, Mass., U.S.A.

Broad Avenue at Linden, Ridgefield, N. J. **NEW YORK AREA** 1000 N. Seward St. **LOS ANGELES 38**

8055 13th St. Silver Spring, Md. **WASHINGTON, D. C.** 1150 York Road, Abington, Pa. **PHILADELPHIA**

1182 Los Altos Ave., Los Altos, Calif. **SAN FRANCISCO** 6605 W. North Ave., Oak Park, Ill. **CHICAGO**

In **CANADA:** 99 Floral Parkway, **TORONTO 15**

All G-R Products are now covered by a *2-Year Warranty*

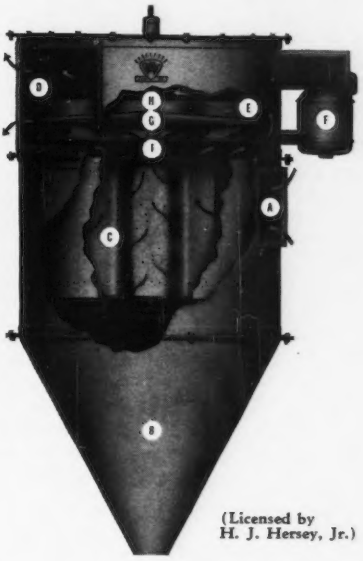
DAY

TYPE "RJ" DUST FILTER

HOW THE DAY "RJ" FILTERS and RECOVERS DUST MORE EFFECTIVELY

Dust laden air enters inlet (A), travels around and down discharging heavy particles into hopper (B). Air containing fine dust particles travels up to felted filter media (C). The dust is stopped by the filter media and the clean air leaves the unit through outlet (D).

To maintain porosity and constant back pressure filter sleeves (wool or synthetic fibers) are counter-flowed one at a time. As cylinder (E) is rotated by motor (F), piston (G) is raised and spring (H) is compressed. When counter-flow duct (I) reaches its position directly over one filter sleeve, an air seal is made eliminating the flow of air through this particular sleeve. At that moment piston (G) is released. Spring (H) plunges piston (G) to the bottom of cylinder (E) forcing fixed volume counter-flow air, at high velocity, in a reverse direction through filter media (C). This maintains the porosity of the filter media (C). The cylinder continues to rotate to the next sleeve where the same action takes place.



(Licensed by H. J. Hersey, Jr.)

The DAY "RJ" filter maintains its high operating efficiency continually as a result of the nonvariable counter-flow of the felted filtering media. Heavy as well as light grain loadings are handled by any of the five standard units . . . to match most plant requirements.

FOR COMPLETE INFORMATION AND SPECIFICATIONS WRITE TODAY FOR BULLETIN G-579.

The **DAY** *Company*

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The DAY SALES Company

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Branch Plants: Buffalo, Ft. Worth

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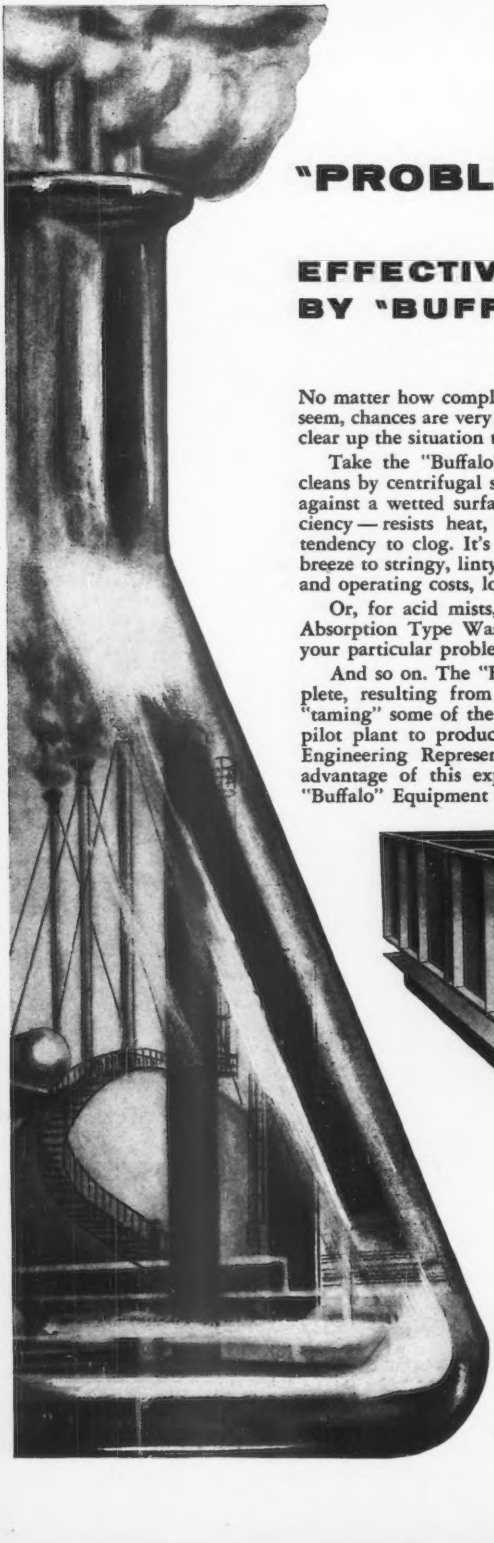
DAY

SINCE 1881

STOP AIR POLLUTION with DAY DUST CONTROL



"PROBLEM" EFFLUENTS . . .

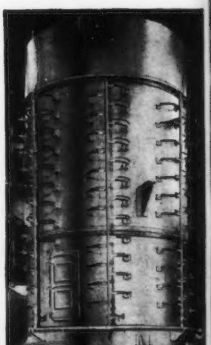
EFFECTIVELY CONTROLLED BY "BUFFALO" EQUIPMENT

No matter how complex your air cleaning problem may seem, chances are very good that some "Buffalo" unit can clear up the situation to your complete satisfaction.

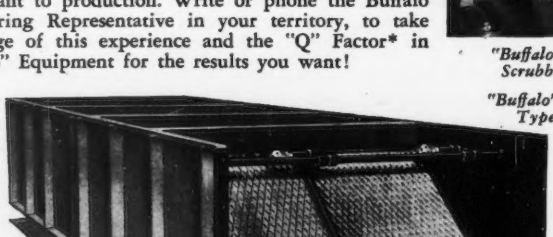
Take the "Buffalo" Hydraulic Scrubbing Tower. It cleans by centrifugal spray action, plus scrubbing action against a wetted surface — provides high collection efficiency — resists heat, corrosion and abrasion — has no tendency to clog. It's controlling everything from coke breeze to stringy, linty discharges. Maintenance is simple and operating costs, low.

Or, for acid mists, fumes and vapors, the "Buffalo" Absorption Type Washer may be the best solution for your particular problem.

And so on. The "Buffalo" line of equipment is complete, resulting from a half-century of experience in "taming" some of the toughest industrial effluents, from pilot plant to production. Write or phone the Buffalo Engineering Representative in your territory, to take advantage of this experience and the "Q" Factor* in "Buffalo" Equipment for the results you want!



"Buffalo" Hydraulic Scrubbing Tower



"Buffalo" Absorption Type Washer

**The "Q" Factor — the built-in Quality which provides trouble-free satisfaction and long life.*

"Buffalo"

BUFFALO FORGE COMPANY

BUFFALO, N. Y.

Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

VENTILATING AIR CLEANING AIR TEMPERING INDUCED DRAFT
EXHAUSTING FORCED DRAFT COOLING HEATING PRESSURE BLOWING

The Uni-Jet† Air Sampler*

- ☆ ***Complete unit weighs less than 2 lbs.!***
- ☆ ***Has Built-in explosion-proof power source!***
- ☆ ***Attention time reduced to less than a minute per sample!***
- ☆ ***Costs only a fraction of other available equipment!***

The UNI-JET AIR SAMPLER U.I.E.-175 is an inexpensive, simplified, self-powered air contamination collector small enough to be held in one hand and weighing less than 2 pounds. This new development substitutes a highly efficient "micro-aspirator" powered by non-flammable "Freon" gas in a safe, low pressure disposable container. Other than a valve to control the propellent (Freon) flow, the UNI-JET AIR SAMPLER contains no moving parts, thereby minimizing operating and maintenance problems.

The outstanding advantages of the UNI-JET AIR SAMPLER lie in its built-in explosion proof power source which permits air analysis in fire hazard areas, compactness, (unit weight less than 2 pounds) and low operational and maintenance cost.

The UNI-JET AIR SAMPLING kit can be carried on a workman's belt with a light, flexible hose extending from the aspirator to the workman's collar, to obtain samples of the same air breathed during routine work assignments without interfering with productivity.

The air sampling rate is determined by the "Freon" gas pressure at the aspirator jet, and is controlled by an orifice inserted between the nozzle and the "Freon" supply valve. A set of 4 orifices permits sampling rates over the range 2 to 10 cu. ft. per hour. Only the time during which the jet operates and the ambient temperature are needed to determine the volume of air sampled from a temperature-compensated calibration chart.

For those applications where continuous indication of air flow is desired, a special unbreakable double range rotometer has been perfected. The Flo-Set rotometer is calibrated from 0-5 liters per minute and 0-10 cubic feet per hour. The Flo-Set rotometer is a positive self indicating measure of the rate of flow through the midget impinger. The needle valve on the propellent source provides instantaneous precision control of the sampling rate.

"Millipore" filter holders provided with threaded adapters for direct connection to the aspirator or the Flo-Set rotometer are a standard stock item. The half inch "Swinny" adapter as well as the one inch Aerosol test results are available upon request.

The efficiency of the "Millipore" Aerosol filters for the collection of air-borne dust and radioactive particles has been well established. Mounted on the UNI-JET AIR SAMPLER, the "Millipore" Aerosol adapters provide a well balanced, reliable, highly effective atmospheric survey instrument.

TECHNICAL DATA AND PRICE LIST ARE AVAILABLE.

UNION INDUSTRIAL EQUIPMENT CORPORATION

20 Davis Avenue **White Plains, New York**

†REGD. T.M. *PAT. PENDING

HOW CLEAN... HOW SAFE

Is the Air in Your Community?

To determine the amount of air pollution . . . You can monitor the atmosphere with A. I. S. I. Samplers

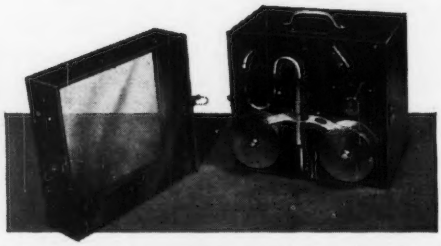
There are two types of A.I.S.I. Samplers—the A.I.S.I. Automatic Smoke Sampler and the A.I.S.I. Hydrogen Sulfide Sampler. Use them to obtain a record over an extended period of air pollution concentration, and to provide data to establish the source and distribution of air pollution. Both samplers operate continuously, so that you can monitor the atmosphere 24 hours a day, at regular intervals of ½, 1 or 2 hours.

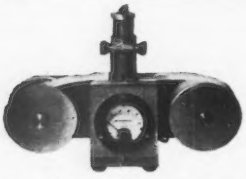
A. I. S. I. AUTOMATIC SMOKE SAMPLER

. . . samples city atmosphere to determine smoke and haze concentration. Because of its low cost you can locate a large number of them for more comprehensive recording; and its quietness overcomes objections to location in residential areas.

A. I. S. I. HYDROGEN SULFIDE SAMPLER

. . . indicates hydrogen sulfide concentration as low as one part per billion parts of air. Operates on same principle as Air Sampler but is fitted with air filter to remove suspended solids; and tape assembly is enclosed to prevent blackening of tape outside sample spot.





TO EVALUATE RESULTS

. . . Research Appliance Company manufactures a Spot Evaluator with which the spots are evaluated by measurements of light transmission.

Write for prices and for complete information on construction, operation and performance details of both the samplers and the evaluator.

RESEARCH APPLIANCE COMPANY

BOX 307 **ALLISON PARK, PA.**

HOW'S YOUR HEALTH?

Check Turco's Big Three for More Certain Plant Safety

Whatever your cleaning problem, Turco has a compound to do the job *safer*, faster, better. Shown here are three of the many Turco materials that produce safer, more efficient plant operation.

Three good reasons why America's safety-conscious plants turn to Turco... first!

1

OILIFT
For grease-free, **non-slip** concrete floors the **safe**, easy way. Eliminates fire hazards. Contains no caustics or acids. Offers maximum personnel safety. Easy to use, Oilift does the work **chemically.**

2

TURCO-SOLV
Safety solvent to replace dangerous carbon tet in cleaning operations. Nonflammable, nonconductive, fast-drying. Leaves no residue. Especially effective for in-place cleaning of motors, generators, etc.

3

HANDISAN
Complexion-quality mechanics hand soap. Gets grime gently. Nonchapping, nonclogging, free rinsing. Assures better handwashing at lower cost per worker. Available with or without lanolin.

TURCO PRODUCTS, INC.
Chemical Processing Compounds
6135 S. Central Ave. • Los Angeles 1, Calif.
FACTORIES: Newark • Chicago • Houston • Los Angeles

67 SPECIALIZED SERVICE CENTERS—From coast to coast and border to border, Turco specialists and Turco warehouses are in most principal cities. Consult your local classified phone book for the one nearest you.

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TOPICAL
DIMENSIONS
Antiinflammatory
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in
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INCORPORATED IN EXCLUSIVE ACID MANTLE® VEHICLE
pH 5.0
Creme
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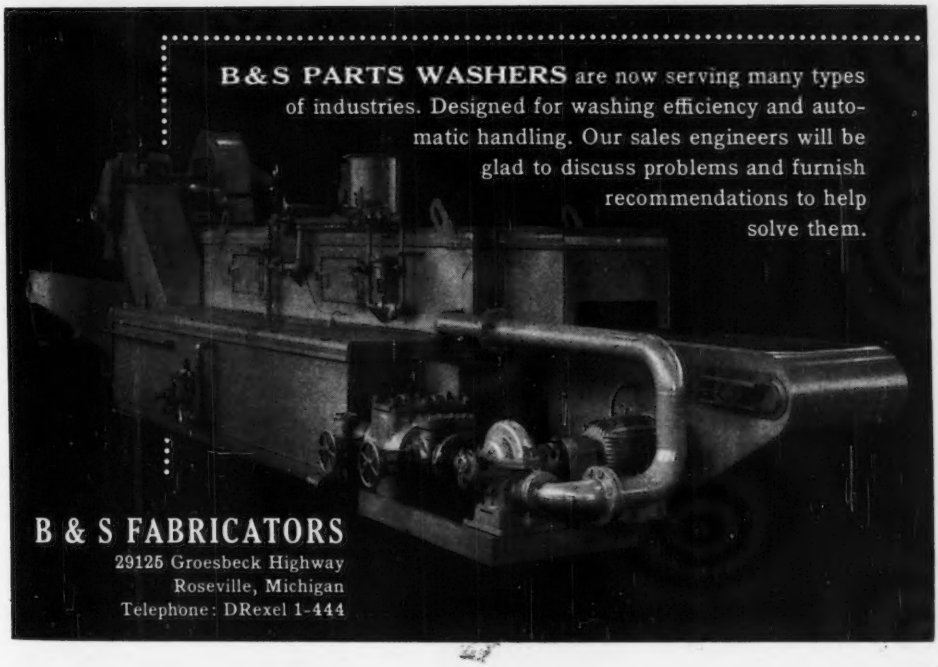
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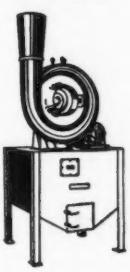

For moderate loadings of dry, granular particles

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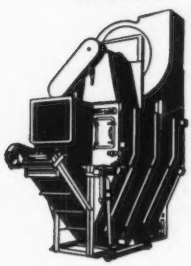

For heavy-duty loadings of all sizes

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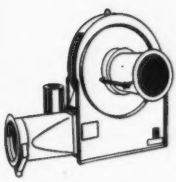

For medium concentrations of fine particles

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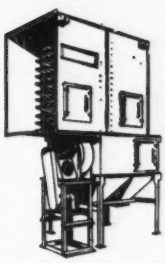

For high concentrations of dry, granular particles in large volumes

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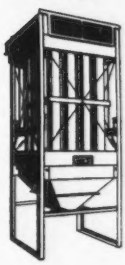

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